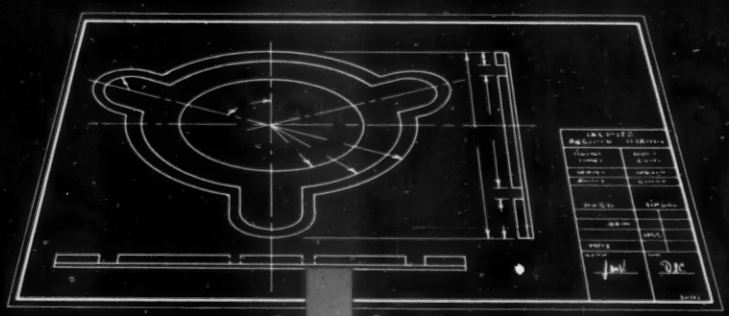
Control ENGINEERING

INSTRUMENTATION AND AUTOMATIC CONTROL SYSTEMS

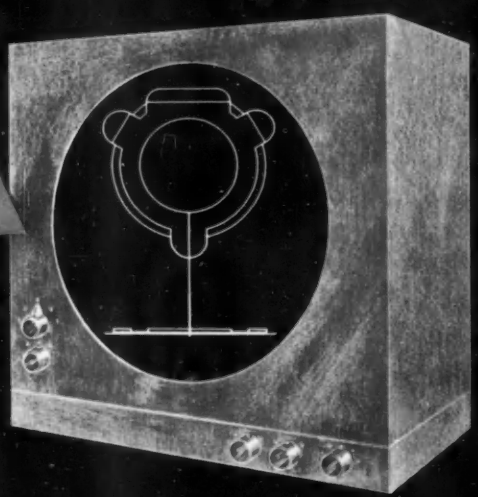
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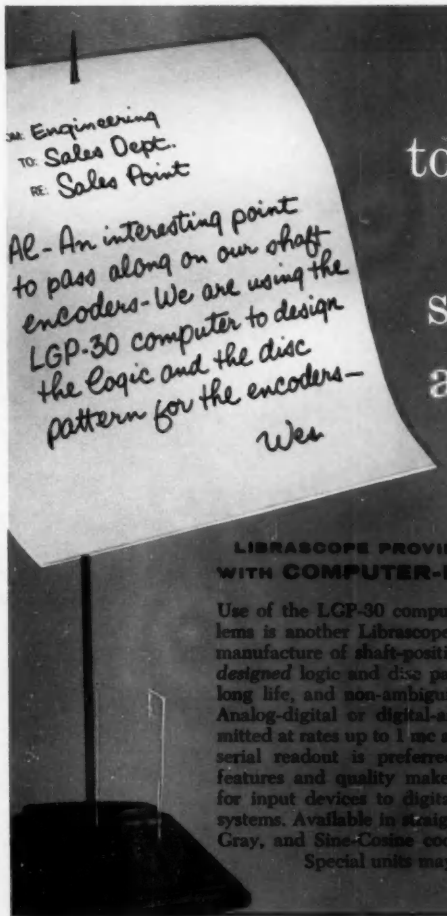


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CODE	MODEL†	Resolution Per Input Shaft Rev. (Counts)	Accuracy Over Full Range	Dimensions Diameter x Length
BINARY	7 digit	128	1 part in 128	2" x 2$^{49}/_{64}$"
	13 digit	128	1 part in 8192	2" x 3$^{19}/_{32}$"
	17 digit	128	1 part in 131,072	2" x 4$^{13}/_{16}$"
	19 digit	128	1 part in 524,288	2" x 4$^{13}/_{16}$"
10 BIT	10 digit	1024	1 part in 1024	4$^{3}/_{16}$" x 1$^{1}/_{4}$"
SINE-COSINE	*	*	1 count in total capacity	4$^{3}/_{16}$" x 3$^{9}/_{16}$"
BINARY CODED DECIMAL	0-2000	200	1 part in 2000	3$^{1}/_{16}$" x 4$^{27}/_{32}$"
	0-3600	200	1 part in 3600	3$^{1}/_{16}$" x 4$^{27}/_{32}$"
	0-20,000	200	1 part in 20,000	3$^{1}/_{16}$" x 4$^{27}/_{32}$"
	0-36,000	200	1 part in 36,000	3$^{1}/_{16}$" x 6$^{3}/_{8}$"
GRAY	8	256	1 part in 256	3$^{1}/_{16}$" x 1$^{11}/_{16}$"

†SPECIAL UNITS AVAILABLE

Precision gearing
Shaft Speed: 120 rpm continuous
Operating temp: −55°C to +75°C
Shock and Vibration: up to 15 G, 5 to 500 cps.

Life Expectancy: Function of lead current. For 13 digit unit @ 2 ma. per brush, life approx. 5 x 10^8 breaks or makes at approx. 120 rpm.

* 8 digits per quadrant plus the limit 1 plus polarity information. One turn of the input shaft generates 4 quadrants of information. Sine and cosine functions available simultaneously and independently.

LIBRASCOPE COMPUTER DESIGNED SHAFT-TO-DIGITAL ENCODERS



DIGITAL READOUT EQUIPMENT AVAILABLE

Librascope's use of the LGP-30 computer simplifies complex design and production problems, and assures computer engineered quality in meeting design and delivery schedules.

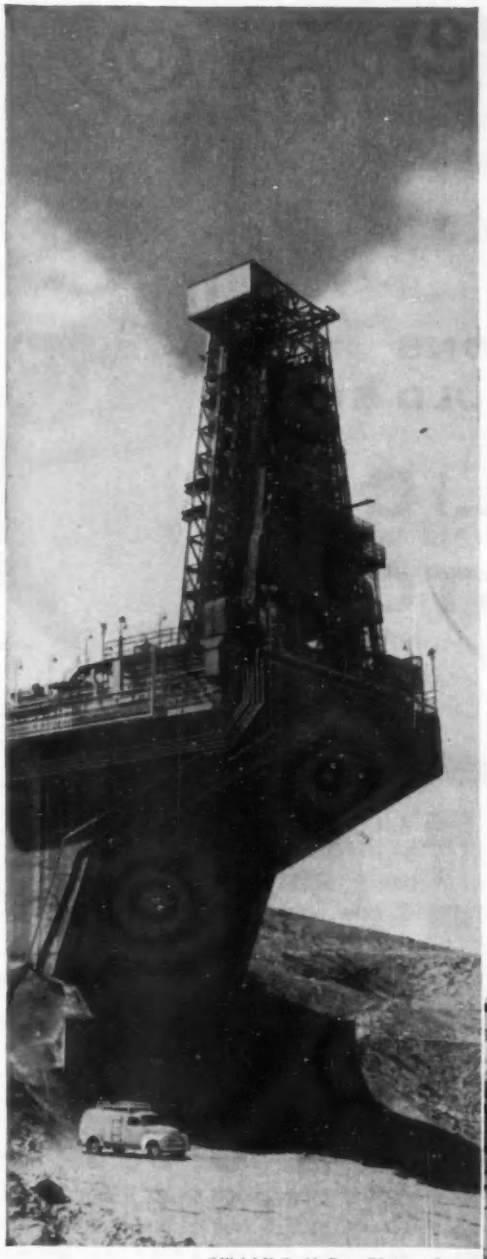


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When the stakes are high...

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This is true of the scientists and engineers here at the Rocket Engine Test Laboratory, Edwards Air Force Base, California. Because they work with the Thor, Atlas and the secrecy-cloaked missiles of the future, they require instrumentation of unquestioned accuracy and dependability. To monitor thrust, flow, force and temperature parameters, they are using more than 600 Speedomax® G Recorders . . . part of one of the most extensive data recording systems in the United States.

Result: throughout more than five years of operation, Speedomax Recorders involved in data gathering have surpassed the exacting performance standards required by Edwards' instrument engineers.

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Data from the 1-A (above) and 1-6 (below) control rooms help Edwards' scientists evaluate missile performance.

"New Horizons", L&N's Tech. Pub. ND46 gives data on circuitry and performance characteristics of Speedomax instruments. Get a copy from your nearest L&N Office or from Leeds & Northrup Co., 4918 Stenton Ave., Phila. 44, Pa.



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6. Made by the reliable *fusion-alloy* process

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Temperature Range −65°C to +160°C

JETEC-30 Type	Reverse Current at −20V		V_{CE} Max. Volts	H_{FE} ave. at I_B=−0.1mA V_{CE}=−0.5V	Base Resistance ohms	Collector Resistance kilohms	Noise Figure db (max.)	Collector Capacity μμf	Alpha Freq. Cutoff KC
	Collector μA	Emitter μA							
2N327A	0.005	0.005	−40	15	1200	500	30	65	200
2N328A	0.005	0.005	−30	30	1400	500	30	65	300
2N329A	0.005	0.005	−20	60	1500	500	30	65	400
2N330A	0.005	0.005	−20	25	1300	500	15	65	250

NPN SILICON TRANSISTORS
Temperature Range −65°C to +160°C

JETEC-30 Type	Reverse Current at 20V		V_{CE} Max. Volts	H_{FE} ave. at I_B=0.5mA V_{CE}=1.5V	Base Resistance ohms	Collector Resistance kilohms	Noise Figure db (max.)	Collector Capacity μμf	Alpha Freq. Cutoff KC
	Collector μA	Emitter μA							
2N619	0.005	0.005	40	15	2000	500	30	35	200
2N620	0.005	0.005	35	30	2500	500	30	35	350
2N621	0.005	0.005	30	60	2700	500	30	35	500
2N622	0.005	0.005	30	25	2400	500	15	35	300

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Control ENGINEERING

AUGUST 1958 VOL. 5 NO. 8

Published for engineers and technical management men who are responsible for the design, application and test of instrumentation and automatic control systems

How to Calculate a Control Earning Index—Part I

W. E. VANNAH of CONTROL ENGINEERING develops an index that will enable a control engineer to predict the increment of improved economy creditable to new controls.

Visual Check for Taped Machine Programs

R. A. BENNETT of The Martin Co. reveals an unusual diagnostic routine that produces a pictorial display of the part as embodied in the data emerging from the data processor.

Improving the Performance of Flat-Armature Torque Motors

R. D. ATCHLEY of Raymond Atchley, Inc., describes the special techniques and drive circuits that permit a designer to get better response and resolution from a torque motor.

Automatic Timer Measures Period of Servo Oscillation

J. COLKER of I. W. Fecker, Inc., tells of a unit that automatically times one full oscillation of an output shaft and presents the measured value by means of clock display.

Data File 19—Get Maximum Accuracy from Dip-Tube Systems

M. J. KELLY of ORNL, summarizes the results of an extensive survey made at Oak Ridge National Laboratory, evaluating the factors that affect accuracy in dip-tube systems.

Five Examples Show Versatility of Automatic Testing Systems

L. S. KLIVANS of Radioplane covers five automatic testing systems that will check out a variety of equipments, from an individual relay to a complete cruise autopilot system.

Unity-Coupled Shear Orifice Yields Reliable Servovalves

T. J. THOMAS of GPE Controls, Inc. uses a totally different approach to the design of electrohydraulic feedback amplifiers to produce a valve with only two moving parts.

X-Ray Techniques for Analyzing Product Streams

P. S. GOODWIN of Applied Research reviews both the x-ray fluorescence technique—for on-line use—and the x-ray diffraction technique—essentially a laboratory procedure.

Discarded Welder Controls Creep-Test Heating

L. W. McMAHON of Douglas Aircraft assembles a temperature controller from scrap.

Bomarc Data-Dubbing technique is Precise, Simple

H. M. KRIEGER of Boeing simplifies dubbing with scope technique to start recording.

Simple Controls Can Eliminate Product Damage

Thermostatic controls on medical suture washing machine saved several percent of output.

Complex Controls Can Pay in Production Testing

Special system tests coolant flow control valves for pressurized-water atomic reactor

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Control ENGINEERING

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- **Process control stars at ACHEMA** as Europeans see latest in systems, instruments.
- **Automation exhibition shrinks** as exhibitor, visitor interest pales at 1958 show.
- **A talk with the Russians** sheds more light on the status of Soviet technology.
- **Underwater telemetry systems** indicate growing interest in Navy's Polaris missile.

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His personal broad engineering experience mirrors itself in a diversified product line.

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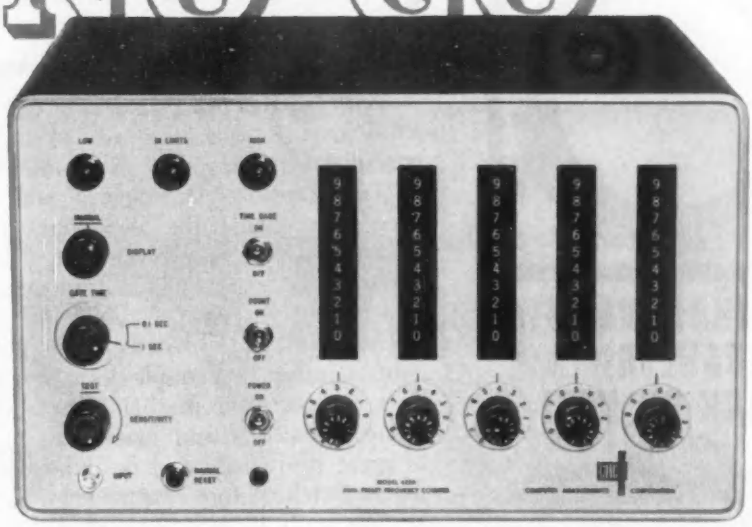
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GO-NO-GO



For production testing and process control

CMC *announces the Model 620A*

ELECTRONIC GO-NO-GO GAUGE

Here's an interesting new instrument from CMC with a host of applications in production testing and process control.

The Electronic Go-No-Go Gauge monitors any control or limiting situation which can be stated in terms of frequency. For instance, in the electronics industry relatively unskilled workers can tune oscillator circuits, filter networks, etc. with great accuracy. Frequency stability and comparison checks can be made quickly and easily. In mills and factories producing a continuous flow of goods such as steel, rubber, paper, the device can be used as a material flow controller keeping the output in tune with the input, preventing line buckle and stretch-out. In chemical and petroleum processing, the Model 620A can serve as a pressure or liquid flow regulating indicating system. Wherever motor speed control is a problem, the Model 620A will hold the speed within preselected limits.

How it Works

In operation, the unknown frequency generated by either the unit under test or one of the many types of transducers on the market is applied at the input. Upper and lower frequency limits are selected by setting the control knobs on the front panel. If the unknown frequency falls below the lower limit, a red "low" lamp lights. Equal to or above the higher limit, a red "high" lamp lights. Within either limit, a green "in limits" lamp lights. Relay contact closure for external control occurs at each lamp condition.

Actual input frequency is displayed on decades. Remote visual monitoring can be obtained with CMC's new Inline-Inplane *Readable* Readout. Use of CMC's new fast printer provides a permanent printed record.

Like all CMC instruments, the new Model 620A features unitized construction for structural strength and low weight.

KEY SPECIFICATIONS

FREQUENCY RANGE	1 – 40,000 cps
INPUT REQUIREMENTS	.05v rms: 10 – 40,000 cps .07v rms: 1 – 10 cps Positive Pulse Rise Time: ½ volt or more/sec.
ACCURACY	±1 count ± stability
STABILITY	0.1% (Normal power line stability) Crystal time base optional.
TIME BASES	0.1 sec. and 1 sec. (10 sec. optional)
READOUT	4 digits (5 digits optional)
DISPLAY TIME	Automatic: Continuously variable 0.1 to 10 seconds. Manual: Until reset
INPUT IMPEDANCE	0.5 megohm and 50 mmfd
PRICE	$1120.00 f.o.b. factory

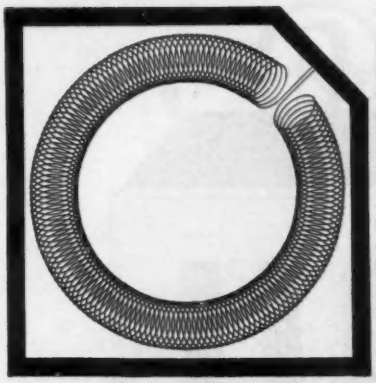
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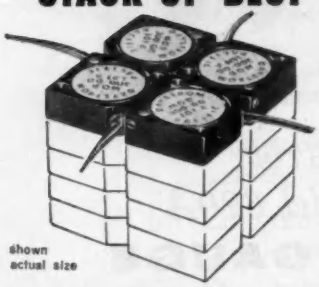
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SHOPTALK

Previewing the September program

As all tried and true readers of CtE know, each September anniversary issue is "themed" to an important phase of the control engineering field. Next month's issue, our 49th, will be no exception. After several staff meetings last fall, the decision was made: the '58 September issue, marking the start of our fifth year of publication, would cover the design and application of program controllers——a new and expanding area of control systems engineering.

Every automatic system has a program controller. The controller may be a simple device like a pot or selector switch, or a complex system that reflects the lengthy routines of today's processes and machines. New program controllers of great complexity and flexibility have appeared. Nurtured in the machine tool control field, these controllers are now finding application across industry.

Quarterbacked by Associate Editor John Cooney and ably backstopped by Mr. Recorded Information Control himself, Dr. Harry Mergler of Case Institute (a CtE consulting editor), next month's issue will tell you how to select, design, and apply all types of program controllers, and will detail a variety of interesting applications.

Improve performance and earning power

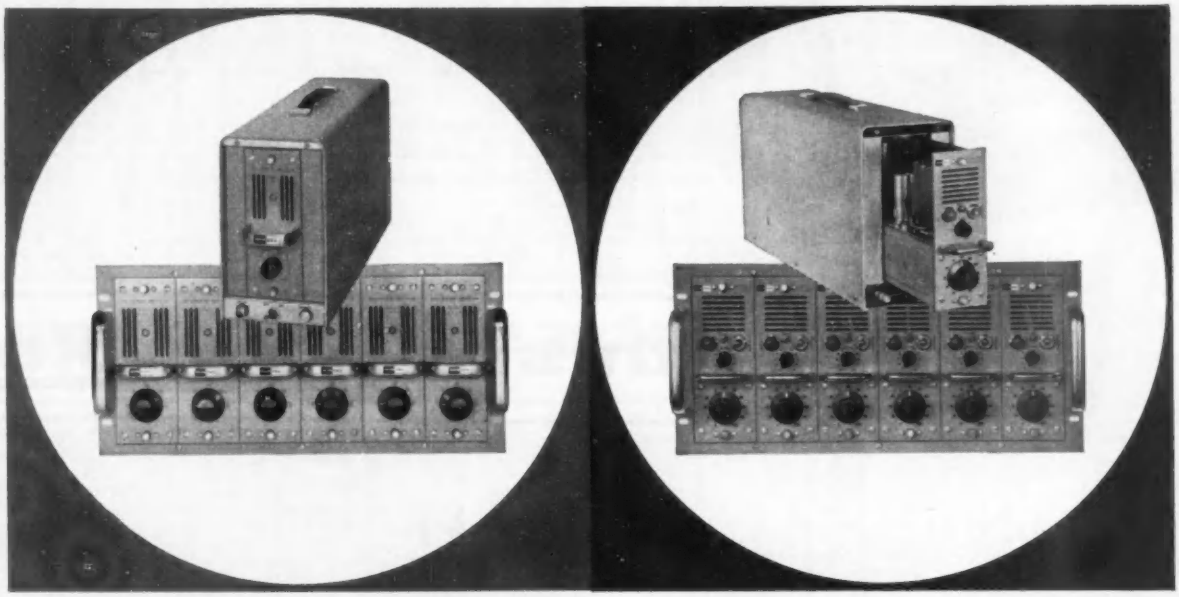
Recent surveys have shown that much of the equipment and many of the procedures used by American industry are obsolete, and therefore totally inadequate to cope with the large——but competitive——markets of the future, or with the task of coming out on top in the economic cold war. With an eye on these surveys, the McGraw-Hill Publishing Co. will embark on a companywide campaign this fall to show the latent benefits of modernizing existing facilities.

This is a natural for CONTROL ENGINEERING, since many of the improvements in performance and productivity will be brought about by automatic equipment. Right now CtE editors are scouring the country for information on how to find opportunities for adding control systems, and for supporting case histories. It will all be digested for presentation in one of the fall '58 issues.

Moving forward in process control

After polishing up his crystal ball, Editor Bill Vannah gave his forecast of "What's Ahead in Process Control" at the Golden Jubilee of AIChE, celebrated at the Bellevue-Stratford in Philadelphia. Bill presented data on the variable influences on process control and risked establishing numerical odds on how rapidly various types of process control equipment will increase in usage. "Know your process and watch for the results that will spin off from present process and control research," was his final word.

AMPLIFY MICROVOLTS WITH STABILITY... measure strain, temperature, other phenomena, to 0.1% with a KIN TEL DC amplifier



NEW...TRUE DIFFERENTIAL DC AMPLIFIERS ELIMINATE GROUND LOOP PROBLEMS...RESCUE MICROVOLT SIGNALS FROM VOLTS OF NOISE

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Ideal for thermocouple amplification, the Model 114A differential DC amplifier eliminates ground loops; allows the use of a common transducer power supply; drives grounded, ungrounded or balanced loads; permits longer cable runs; and can be used inverting or non-inverting. The 114A can be mounted in either single amplifier cabinets or six amplifier 19" rack adapter modules. Price: 114A – $775; six amplifier module – $200; single amplifier cabinet – $125.

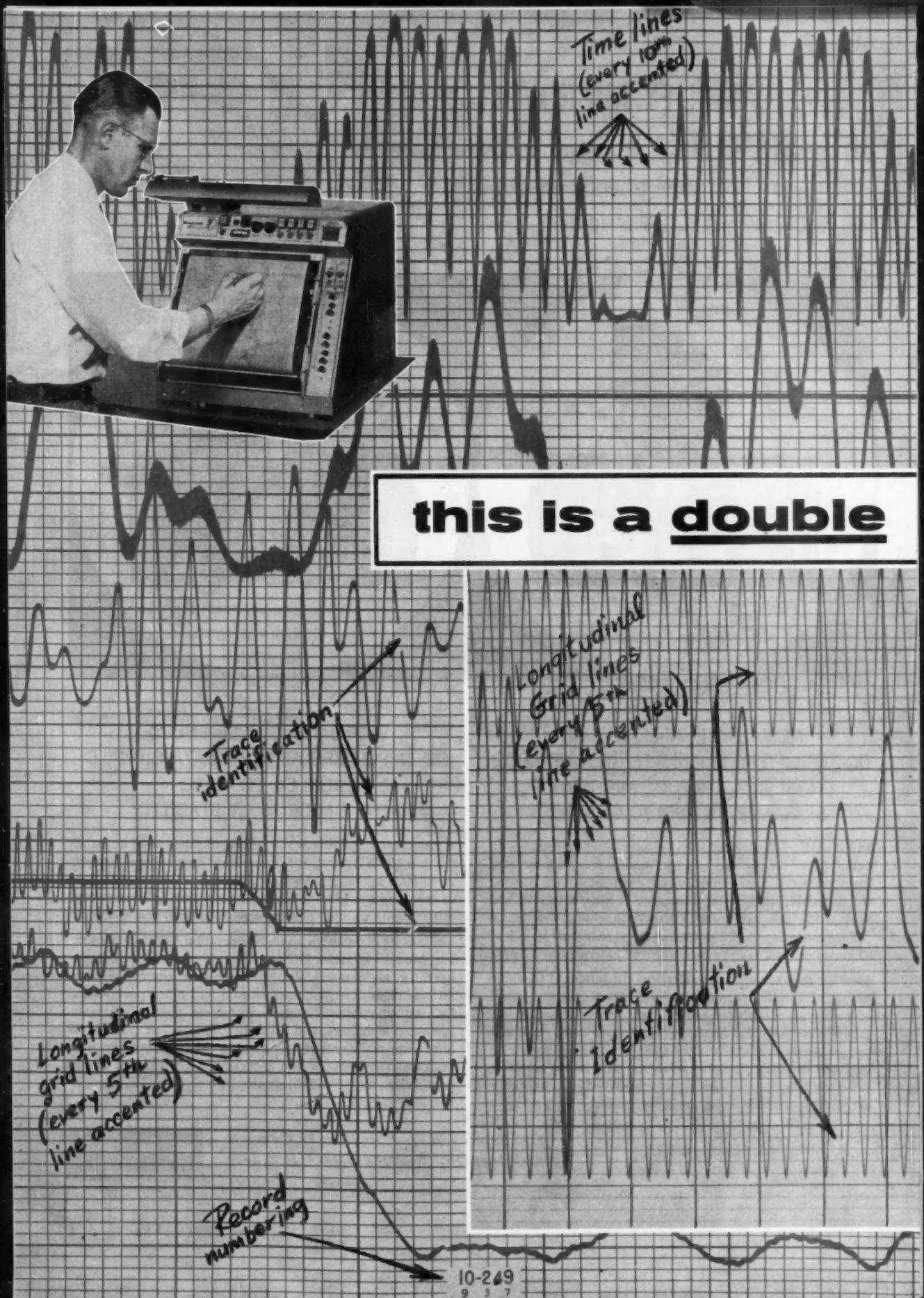
WIDEBAND, SINGLE ENDED DC AMPLIFIERS AMPLIFY DATA SIGNALS FROM DC TO 40 KC WITH 2 MICROVOLT STABILITY

±2 microvolt stability ■ <5 microvolt noise ■ 40 kc bandwidth ■ 100 KΩ input, <1 ohm output impedance ■ Gain of 20 to 1000 in ten steps with continuous 1 to 2 times variation of each step ■ ±45 V, ±40 ma output ■ 1.0% gain accuracy ■ 0.1% gain stability and linearity ■ Integral power supply

Millions of cumulative hours of operation have proved KIN TEL Model 111 series DC amplifiers to be the basic component for all data transmission, allowing simple, reliable measurement of strain, temperature and other phenomena. DC instrumentation systems – with their inherently greater accuracy, simplicity, and reliability than AC or carrier systems – are made entirely practical by the excellent dynamic performance, stability, and accuracy of KIN TEL DC amplifiers. Price: 111BF–$575; six amplifier module–$200; single amplifier cabinet – $125.

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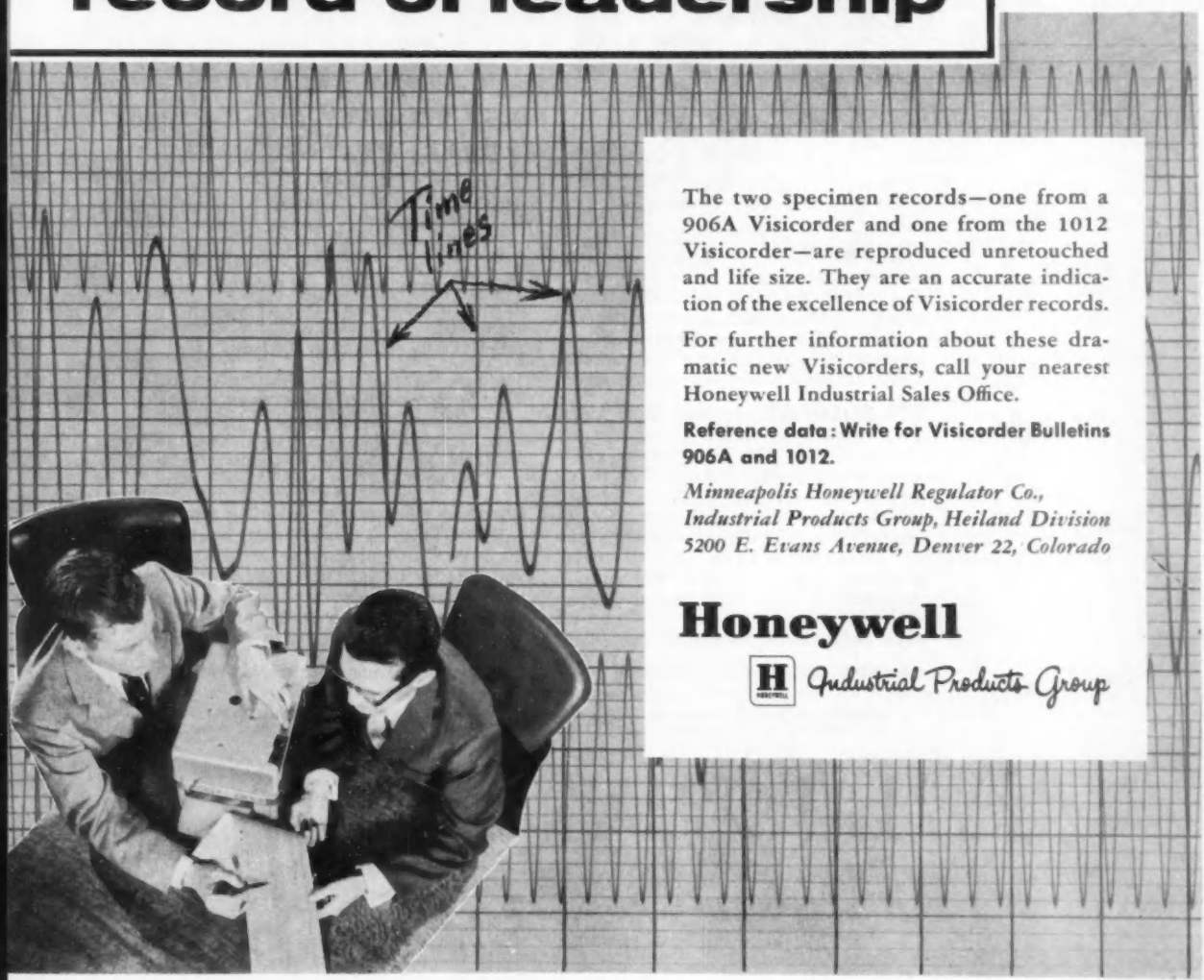

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For further information about these dramatic new Visicorders, call your nearest Honeywell Industrial Sales Office.

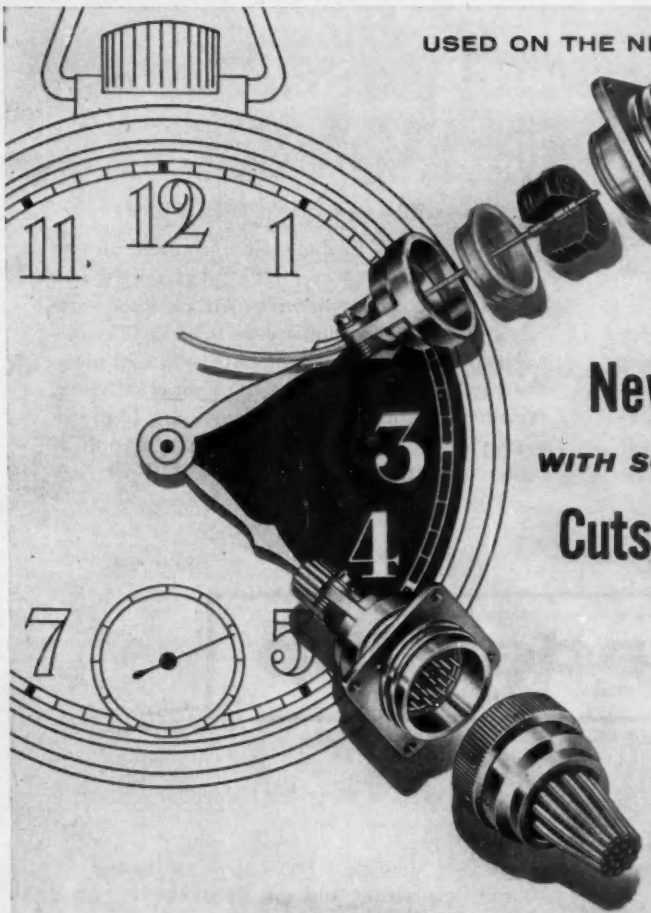
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FEEDBACK

APPLICATION FORUM

The Forum presents problems, solutions to problems, and application experiences reported by readers. All earn honoraria. This month a reader relates his experiences in applying the techniques described by C. J. Doda, "Digital Computer Makes Root Locus Easy", pages 102-106 of the May issue.

To the Editor—

Back in the early part of 1956, when with North American Aviation, Inc., I used the method described in Mr. Doda's article quite extensively for the study of automatic flight control systems. I feel that the method is even more useful than was indicated in the article, for the following reasons:

1. With this method it is possible to obtain a locus-of-roots plot for variations in any system parameter. This is not always possible by the hand plotting method, e.g., if the parameter cannot be factored out as a "gain" term.

2. This technique makes it very convenient now to study the effect of variations in at least two parameters simultaneously. This is accomplished by plotting a "carpet" or "map" of the roots of the system determined by many combinations of those parameters. The figure shows an example of this use for a system having two time constants which could be varied independently. Actually, both of the time constants could not be reduced physically below certain minimum values, so the plot indicates the optimum value of τ_2 for any given value of τ_1.

We sometimes used the digital computer for making complete root-locus plots, including the "zeros", as follows:

1. The variable parameter was set equal to zero and the roots were determined by the machine. The roots obtained were the "poles" of the system and were plotted as "x's."

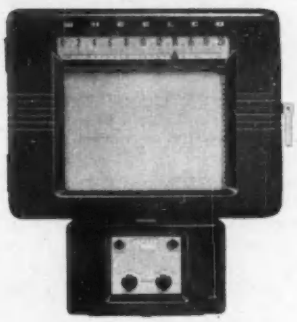
2. The variable parameter was set equal to a very large number and the roots determined by the machine. (In our program it could be as high as 10^{∞}.) The roots that were convergent were (very nearly) the "zeros" and were plotted as "0's." If there were more poles than zeros there would be roots which did not converge. A very large real root would indicate a branch

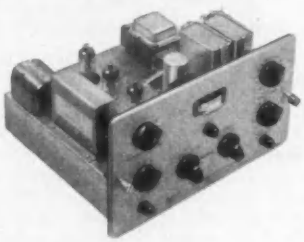
THE MARK OF QUALITY

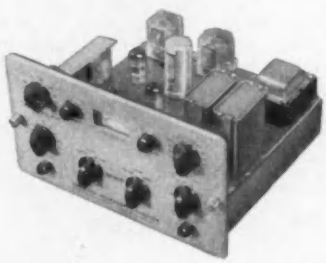
BARBER COLMAN

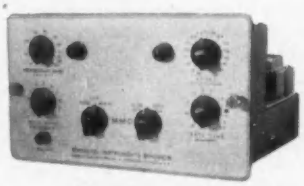
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Need proportional reset and rate action? Choose from four controller types – that include magnetic modulation – by Wheelco









Start with this production-proved Wheelco Series 8000 recorder-controller and add the MM Series controller* from four types (three magnetic modulated) available to insure getting the best installation for your needs. This customizing of systems at standard cost is another example of Wheelco's constant effort to improve performance while holding down costs. Advance design features include plug-in components and tamperproof covers to protect critical adjustments.

MMC-Current Output Type—Flexible in adaptation to final control elements including saturable reactors, electropneumatic transducers, electro-hydraulic transducers, etc. . . . proportional band adjustable from 2 to 200% of controller range . . . reset action from 0 to 63 repeats per minute . . . rate action adjustable from 0 to 5.5 minutes.

MMP Position Type—Together with potentiometer can position a valve, valve positioner, or other positioning device . . . reset action adjustable from 0.6 to 100 repeats per minute . . . proportional band adjustable from 2 to 200% of controller range . . . rate action adjustable from 0 to 5.5 minutes.

MMD Duration Type—With potentiometer regulates input by adjusting on-time of a contactor on either electrical or fuel-fired installations . . . particularly adaptable when upsets are fast and recovery slow and when they are frequent and of large magnitude . . . keeps overshoot at startup or control point to minimum.

MP Proportional Positioner—Transistorized and printed circuit unit (not shown) where constant voltage source is available as reference voltage . . . mounts inside instrument . . . adjustable from 2 to 40% of recorder range.

*Also usable with Wheelco 2000 and 9000 Series.

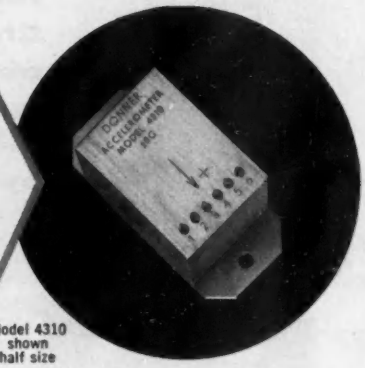
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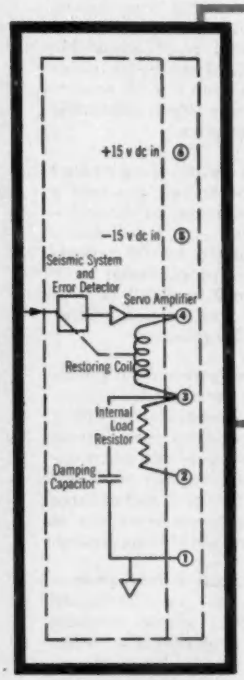
HIGH OUTPUT -HIGH RESOLUTION

0.1% Transistorized Accelerometer



Model 4310 shown half size

Donner's new transistorized Model 4310 accelerometer is designed for demanding measurement and control functions under severe environmental conditions. With applications in telemetering, navigation, control, gyro-erection, and short range inertial guidance, the 4310 is especially appropriate where low weight, small size, and high output are important considerations. When an especially small light weight sensing unit is needed, the acceleration sensing portion of the instrument can be separated from the servo-amplifier. Typical applications in this category include gyro and platform measurements of acceleration, velocity, and displacement.



OPERATIONAL HOOKUPS OF 4310

A variety of specific output arrangements are possible with the standard Model 4310 Accelerometer. For a full scale voltage output of approximately ±7½ volts, jumper terminals 1 and 2, read output across 1 and 3. For a full scale current output of approximately ±1.5 ma, connect a series load between terminals 1 and 2. For a standardized voltage output, connect a resistive voltage divider network across 1 and 3 with a total resistance of approximately 5000 ohms to yield any prescribed output below ±7½ volts full scale. Standard modifications of the 4310 include provision for biasing of output; fluid-filling for mechanical rejection of high frequency vibration; and operation from 0-28 volts dc or ±28 volts dc with higher output.

KEY SPECIFICATIONS

NON-LINEARITY PLUS HYSTERESIS	Within 0.05% deviation from best fitted straight line
STANDARD RANGES	Between ±0.1 g full range and ±30 g full range. Lower and higher ranges available on special order.
RESOLUTION	Better than 0.0002% full scale
WEIGHT	3.5 ounces net
OUTPUT	±7½ v dc and/or ±1.5 ma full scale
EXCITATION	Plus 15 v dc, 5 ma max.; minus 15 v dc, 5 ma max.
DOMESTIC PRICE	Standard instrument $450.00 F. O. B. Concord, California. Modifications extra.

Donner engineering representatives are located in principal areas. For the name of your nearest representative and complete technical information, please address Dept. 088.

DONNER SCIENTIFIC COMPANY

CONCORD, CALIFORNIA

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FEEDBACK

of the locus extending out to infinity along the real axis. Very large complex roots would indicate conjugate branches extending out to infinity and approaching asymptotes whose angle relative to the real axis could be computed as the arc-tangent of the ratio of imaginary to real parts.

3. The roots were computed for several intermediate values of the variable parameter in the region of greatest interest. They were plotted and connected with lines, beginning at the poles and terminating at the zeros, or extending to the edges of the graph in the directions indicated by the non-convergent roots, if any existed.

The program which we used first expanded a determinant and then factored the resulting polynomial. In order to use the method, then, it was only necessary to write the Laplace-transformed equations of motion, including the control equations, in a series of rows, keeping like variables in columns. The computer programmer and the machine then did the rest. This meant that very little knowledge of the root locus technique or facility with arithmetic was required of the engineer setting up the problem. This in itself was a major advantage!

R. M. Fleming
Los Angeles, Calif.

Textile mill wants data logger

TO THE EDITOR—

In the May 1958 issue of CONTROL ENGINEERING appears an article concerning a data logging system for piecework production control. This item appears on pages 25-26.

You mention the name Control Systems Co. as marketing the Telecontrol System for Hancock. Would you please forward to my attention the complete name and address of this firm? As a matter of interest, do you know of any other systems embracing this idea. If so, please forward their names and addresses.

Edward S. Olson, Process Engineer
Excelsior Mills, Inc.
Worsted Div.
Pendleton, S. C.

The Control Systems Co., a division of Hancock Mfg. Co., is located in Jackson, Mich. With regard to the Telecontrol application in the textile industry, see the February 1958 issue of "Textile World", page 102. The article starting on that page describes a mass-counting system for loom operations developed by the Kendell Co.,

beneficial occupancy

of test sites .... is the crux of efficient missile development



AND ON-TIME ACTIVATION OF TEST SITES IS THE PRINCIPAL PRODUCT OF PAP'S SYSTEMS ENGINEERING

The enormous benefits in terms of economy and adherence to schedule that result from on-time availability of test and launch sites are well understood by all missile developers. Almost as well-known is the fact that every site for the Atlas missile program has been completed on-or ahead of schedule.

PAP's vital tasks in this accomplishment have included design, manufacture, and installation of all electronic cable; installation of instrumentation, controls, consoles, and accessories; and checkout and validation of the complete electronic complex.

PAP has demonstrated its ability to modify test stands in support of missile design changes in less time, at lower cost — therefore PAP can best support your firing schedule.

For a complete report on PAP's performance on the Atlas program, or for a prompt proposal on the services that can be supplied on other missile programs, address Arthur P. Jacob, Executive Vice-President.

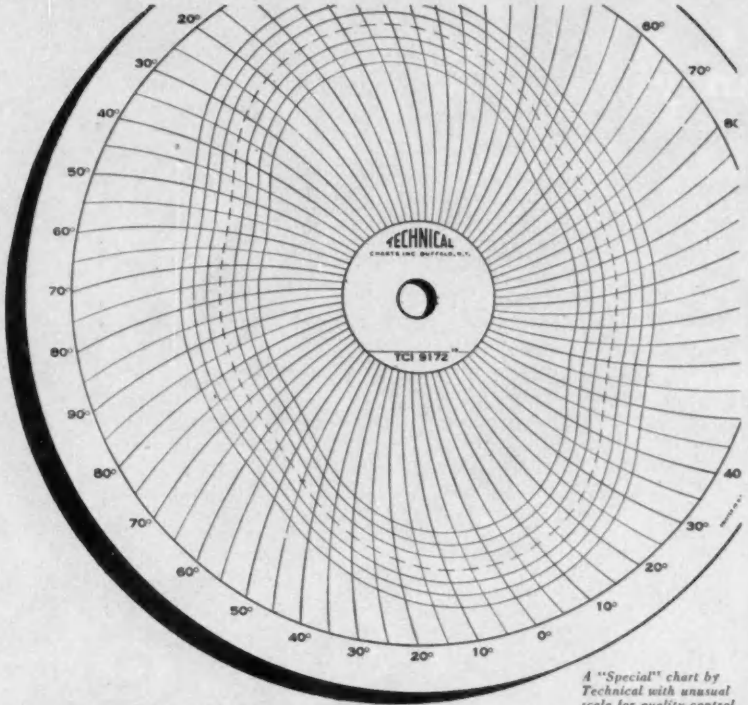
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Ask Technical to prepare your charts for instruments of your own design, or recordings under unusual conditions!

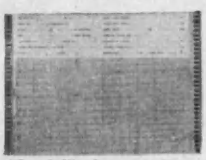
The choice of the recording *paper* on which your charts are printed can help to solve a wide range of recording problems. Technical has special papers for direct production of recordings, papers with dimensional stability, others that are heat or electro sensitive . . . and more.

Technical will help you engineer "special" recording charts by consulting with you on size, shape, scale and choice of paper to give you charts to fit your specifications exactly. For some types of charts, Technical is the only firm in America that has the experience and facilities to meet your needs.

Write for catalog.



"Special" chart with unusual grid pattern for quality control of gear teeth.



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FEEDBACK

Newberry, S. C., and Strandberg Engineering Labs. Ed.

For dole-free education

TO THE EDITOR—

You are to be commended for your editorial, "Keep Technical Education off the Dole". You have done well bringing into focus an issue (technical education) that must be resolved and whose very existence and future worth rests upon an independence of action free from any system of *dole*.

M. J. Goglia
Georgia Institute of Technology
Atlanta, Ga.

Erratum 1

TO THE EDITOR—

May we call your attention to an incorrect caption on page 54 of the April issue of CONTROL ENGINEERING. The upper right-hand photograph is of Mr. W. T. Griffiths, president, Anders-Lykens Corp., and not Mr. R. A. Bennett, chief mechanical research and development engineer of Milton Roy Co.

The release on Mr. Griffiths' election to president of Anders-Lykens Corp. was sent out with the releases on Mr. Bennett's and Mr. Klembeth's promotions. In all cases, Mr. Griffiths' photograph was to be labeled. No photographs were sent of Mr. Bennett and Mr. Klembeth.

We are very sorry if this mistake was caused by improper handling on our part.

John W. Segraves
Milton Roy Co.
Philadelphia, Pa.

Our congratulations to Messrs. Griffiths, Bennett, and Klembeth. Regrets to Mr. Segraves and ourselves. Ed.

Erratum 2

TO THE EDITOR—

In your article in the March 1958 issue of CONTROL ENGINEERIN, entitled "Guide to Equipment Costs for Industrial Pressure Measurement", under Table 1, "Ranges for Pressure-Sensing Elements", there is between 10 and 10^{-3} mm Hg the figure 0. Since 0 mm Hg or "absolute zero" is impossible to obtain, I believe this should be 1 instead of 0.

James M. Spence
Union Carbide Chemicals Co.
South Charleston, W. Va.

You are absolutely correct. Ed.

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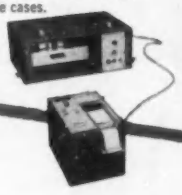
Permits convenient, variable speed editing and study of Sanborn charts and other types up to 16" wide, 200 ft. long. Single control for direction, paper speeds (15" to 100"/min). Transparent cursor slides left or right, adjusts for accurate alignment with coordinates.

1- TO 8-CHANNELS, 12 PLUG-IN PREAMPLIFIERS

150 SERIES



Features of the "150 series" direct writers include: frequency response to 100 cps; linearity 1% overall; inkless recording in true rectangular coordinates by heated stylus on plastic coated Permapaper charts; current feedback driver amplifier and regulated power supply for each channel. Recorder has 9 chart speeds, 0.25 to 100 mm/sec; individual stylus heat controls, time-code marker. Up to 6-channels can be housed in one vertical cabinet. Amplifiers, recorder also available in individual portable cases.



6-, 8-CHANNELS, FLUSH FRONT RECORDER, FREQUENCY RESPONSE TO 120 CPS

350 SERIES



New "350" series direct writers with compact plug-in preamps in modules of up to 4; individual power supplies; current feedback transistorized power amplifiers; limiter circuit ahead of power amplifiers; velocity feedback galvanometer damping; enclosed galvanometers. Linearity 0.2 div. over entire 50 divisions. Recorder-power amplifier-power supply package has 0.1 volt/div. sensitivity, can be used separately; pushbutton controls for 9 chart speeds 0.25 to 100 mm/sec; individual stylus heat controls; contacts for remote control; inkless rectangular coordinate recording on Permapaper charts.

6-, 8-CHANNELS

850 SERIES



Compact "850" series direct writers use 7" high plug-in preamplifiers in modules of up to eight and "350" flush front recorder package with transistorized power amplifiers, power supply; features velocity feedback galvanometer damping, linearity 0.2 div. over entire 50 divisions; 9 chart speeds from 0.25 to 100 mm/sec controlled by electric pushbuttons; inkless recordings on Permapaper charts. Available preamps include Servo Monitor (demodulator) and DC Coupling. Carrier, Chopper Stabilized and Low Level types are in development.

COMPUTER READOUT . . . AUTOMATIC PROGRAMMING

150 SERIES



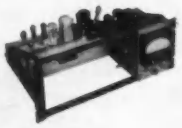
"150 series" 6-, 8-channel consoles in 46½" high mobile cabinet. Dual-Channel Amplifiers have selectable sensitivity from 0.01 to 10 volts/div.; internal calibration 2 volts ±1% freq. response flat to 20 cps. Optional Programmer sequences system operation in 20 steps, including recorder turn-on, calibration, computer DC level reading, recording for pre-set time, turn-off and reset.

SELF-CONTAINED UNIT PREAMPLIFIERS TO DRIVE 'SCOPES, OPTICAL OSCILLOGRAPHS, TAPE RECORDERS, ETC.



Portable "350" series include Carrier, DC Coupling Servo Monitor (demodulator), True Differential DC types; others in development. Mount in portable "450" cases or in four-unit modules in 19" frame. Use individual power supplies. One "450" case and power supply can serve any "350" Preamp.

PORTABLE INDICATORS FOR STRAIN, ETC.



Model 150-300/700 Wide Band Amplifier and Power Supply accepts "150" series preamplifiers — for use with low power galvanometers, oscilloscopes, panel meter. Freq. range DC to 10,000 cps (but limited by particular preamp range). Panel meter has center zero scale, 25 divisions each side of center.

[ALL DATA SUBJECT TO CHANGE WITHOUT NOTICE]

For complete data, call your local Sanborn Engineering Representative or write the Industrial Division in Waltham.

SANBORN COMPANY

Industrial Division

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"VISIT SANBORN BOOTHS 1454-1455 AT WESCON SHOW"

TWO NEW OHMITE® RELAYS

with exclusive "Molded Module"* contact springs

exceptional sensitivity for small size

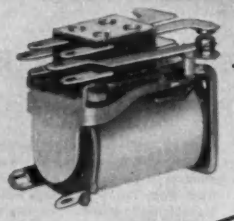
designed to meet aircraft, military, and industrial applications

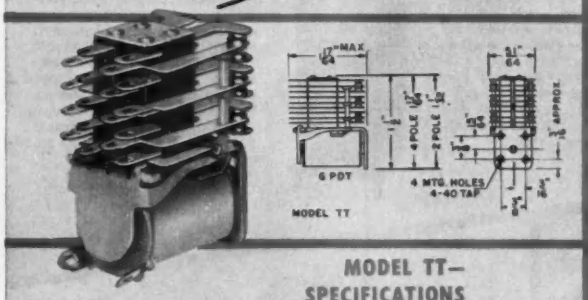
*Patent applied for

The new Models TT and TS relays incorporate several design innovations that make them ideal for aircraft and industrial applications at high ambient temperatures. Both relays are lightweight, yet rugged. Paramount among the design innovations is the revolutionary "Molded Module" contact spring construction. The "module" is a standard, single-pole, double-throw spring combination molded into a single compact assembly. As many as six modules can be incorporated into a relay to provide a maximum six-pole, double-throw combination. With the springs rigidly held in a matrix of tough plastic, alignment of the springs is assured. More accurate alignment of all the subcombinations (modules) on the relay is possible, and adjustment of the individual contact springs is easier and more permanent. Diall Phthallate, the molding material, is capable of withstanding temperatures to 400°F.

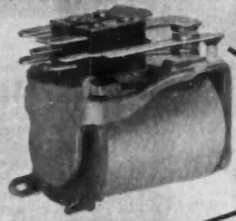
A contributing factor to the remarkable sensitivity of these relays is the design of the armature retaining guard to minimize undesirable heel gap. A wide variety of hermetically sealed enclosures is available.

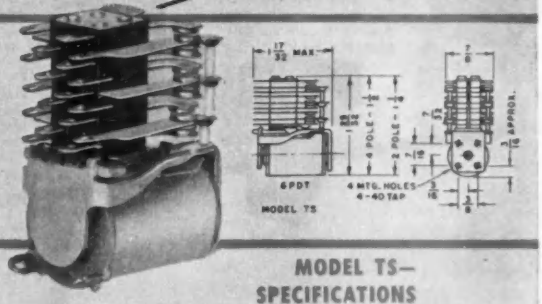
MODEL TT—
Molded Module





MODEL TS—
Molded Module





MODEL TT— SPECIFICATIONS

COIL WATTAGE: Rated nominally at .150 watt per pole at an ambient temperature of 20°C.

COIL OPERATING VOLTAGE RANGE: To 115 VDC.

CONTACT RATINGS: Up to 5 amperes at 115 volts AC or 32 volts DC noninductive, with standard contact material, palladium. Other materials can be supplied.

CONTACT COMBINATIONS: Standard combinations are DPDT, 4PDT, and 6PDT (maximum). Others can be furnished.

WEIGHT: Approximately 2 ounces for 4PDT relay.

MODEL TS— SPECIFICATIONS

COIL WATTAGE: Rated nominally at .250 watt per pole at an ambient temperature of 20°C.

COIL OPERATING VOLTAGE RANGE: To 115 VDC.

CONTACT RATINGS: Up to 10 amperes at 115 volts AC or 32 volts DC noninductive with standard contact material, silver-cadmium oxide. Other materials can be supplied.

CONTACT COMBINATIONS: Standard combinations are DPDT, 4PDT, and 6PDT (maximum). Others can be furnished.

WEIGHT: Approximately 3 ounces for 4PDT relay.

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WRITE FOR BULLETIN 160

John Moore

scouts for generalists

The change from college professor to corporate executive happens frequently now. Another control engineer who has made the switch is John Moore, the dynamic vice-president of North American Aviation in charge of the Autonetics Div. And like many others with an academic background, Moore's professional experience deeply influences what he believes and how he runs his division.

For example, the 42-year-old engineer has become increasingly articulate about the need for what he calls "generalists"—engineers with broad technical backgrounds—as opposed to "specialists". Autonetics Div.'s widely diversified product line (which includes automatic navigation systems, flight and fire control systems, data processing equipment, computers, and machine tool controls) mirrors this regard for broad engineering. Although problems of management take up the bulk of John Moore's time today, he still tries to keep a finger in division technical activities. His own broad technical experience helps.



John Moore started his engineering career at General Electric Co. in 1937, fresh from Washington University with a BSME degree. For three years he was a student on GE's advanced study course, after which he was introduced to the control field. His first assignment: the Aeronautics & Marine Department, doing test work on the old "Mark II" fire control system. "This mechanical monster used gear cams and weighed in at several tons," he recalls. "It properly never got into production. And it was the first time I really got my nose bloodied learning what not to do," he adds.

Although the Mark II work was a sobering experience, it started Moore on a project of improving fire control systems. Out of this came a design for the first airborne fire control computer of a director type. And having completed the theoretical portion of the program, Moore plunged into developing prototype hardware which became the basis for the production design of the B-29 fire-control system.

The success of the B-29 program did not completely satisfy Moore; he was after still a better system. He says, "Concentrating on design of a super-precise computer meant that we were solving the wrong problem very accurately. Of primary importance was to point the gunsight in the direction of the target and keep it pointed there accurately enough to obtain the angular rate of line of sight, the range, and rate of change of range." This conclusion started Moore on the development of gyro-stabilized sights. Dissatisfied with the eddy torque gyros in use at the time, he invented one of his own—the first electrically-torqued gyroscope.

Besides being strong on theory, Moore has always had a knack for handling hardware. When production men found it hard to mass-produce fire-control systems because of their mechanical complexity, he designed a computer that used potentiometers instead of cams. When he found that existing pots weren't accurate enough or small enough for his purposes, he invented an automatic nonlinear precision potentiometer winding machine.

In 1946 Moore left GE to return to Washington University as associate professor of mechanics and director of the Dynamical Control Laboratory. As a professor, he taught graduate courses in guidance and control analysis. As a researcher, he directed studies in missile guidance and control.

A few years later, Moore succumbed to a long-time desire to live in California. He returned to industry as a member of North American Aviation's Navaho project; he's been with that company ever since. In 1955, he was named general manager of its Autonetics Div.; last year, a vice-president.

When he's not following the lures of California sports, Moore still tries to keep an eye on educational activities. Until last year (and for eight years previously) he was a visiting associate professor at UCLA teaching advanced servo courses and classes in the analysis of three dimensional systems. And he's Autonetics' top scout for systems engineers who can meet his requirements as generalists in a world of narrowing specialization.

ANOTHER GREAT ADVANCE

in the automatic control field

due in late '58

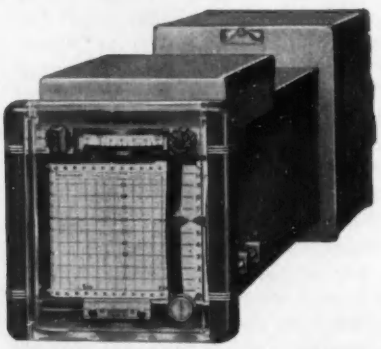
Swartwout has done it again.

In late '58, you'll be introduced to another new concept in the automatic control field. Swartwout has applied new thinking . . . a new principle to the solution of an old control problem.

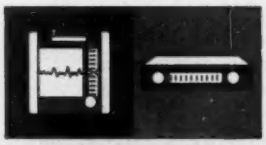
Swartwout is the pioneer and leader in the electronic process instrumentation field. The AutroniC Instrument line has demonstrated performance beyond any expectations. It has set new standards of simplified maintenance and complete flexibility. It has been proven in service and accepted by major segments of industry.

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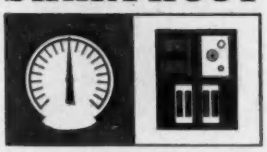
The new development is compatible with every Swartwout AutroniC Controller now in the field or that you now install. It's another step ahead for which you can be prepared . . . with AutroniC Instrumentation installed today.



TODAY with Swartwout AutroniC® Instrumentation, you are years ahead . . . stay ahead.



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THE SWARTWOUT COMPANY
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CLEVELAND 12, OHIO

SA-1637

First Sage Unit Staggers the Eye

"I hope it works," said an Air Force general visibly impressed after touring the first direction center to be built in the SAGE (Semi-Automatic Ground Environment) system, the U.S.'s nationwide air defense system. What he saw at New Jersey's McGuire Air Force Base was enough to make any soldier skeptical. SAGE staggers the imagination. It's size and complexity are awesome.

SAGE is a giant data handling system. It receives inputs from a variety of long range surveillance and gap filling radars (13 different kinds); computes position and velocity of radar tracks; retains such information in magnetic drum and core memories; then presents the air defense picture by a wide assortment of display apparatus and printout devices.

Here are just a few staggering statistics on this first (28 more just like it will be built) SAGE unit: 14,000 sq ft of computers (there are two identical digital machines, one backs up the other); two core memories each with a capacity of 557,056 bits; 58,000 vacuum tubes in each computer; 170,000 diodes and 600,000 resistors; each machine is made up of 7,300 plug-in modules.

Cost of the McGuire AFB direction center is about $64 million. Each computer cost $27 million; other equipment and the 150 by 150 ft sq concrete building that houses all electronics cost another $10 million. When the SAGE system is completed in 1961, it will represent an investment of from $7½ to $10 billion. Maintenance alone will cost $500 million per year when SAGE is operating.

R-W Merger Builds New Control Giant

When Thompson Products, Inc. merged with its affiliate, The Ramo-Wooldridge Corp., last month, the combination set up a new company with combined assets in the range of $200 million, estimated 1958 sales of $300 million.

One advantage of the merger, according to J. D. Wright, president of Thompson Products and now chairman of the board of the new Thompson Ramo Wooldridge Corp., will be easier bidding on government contracts. The two companies can now blend their specialities: Thompson Products in manufacturing and machine tool development; Ramo-Wooldridge in missile study, computer design, and control systems engineering.

Another factor in the merger is the number of long-range development projects under way at Ramo-Wooldridge. The new company plans to continue them, using Thompson's manufacturing facilities to convert the ideas into production hardware.

Wright said that the new company would follow Thompson Products' philosophy of decentralization. However there will be more interchange of information between Thompson and Ramo-Wooldridge divisions. One possibility: studies in numerical control of machine tools at Thompson Products Cleveland plant could be backed up by Ramo-Wooldridge's California computer background.

Headquarters of the new company will be in Cleveland. Dean Wooldridge is the president of the merged corporation; Simon Ramo is executive vice-president.

TRANSIENTS IN CONTROL

Japan's first guided missiles have been successfully ground-tested. The small, 13 ft long, slow speed (454 mph) B-3 has a built-in TV transmission set, is powered by a ram jet engine. Although a flight test is expected early in the fall, it is unlikely the B-3 will go into production.

•

Subroc, the Navy's submarine-fired anti-submarine weapon, is a $65 million project at Goodyear Aircraft. The weapon will be ejected from a submerged submarine to the surface where a solid-fuel rocket will power it to the vicinity of its target. Control system will be an adaptation of Atran, the system developed for the Mace (a modification of the Matador missile).

•

Two separate teams are competing for the Air Force's Dyna-Soar project: Boeing Airplane Co. and the Martin Co. Aimed at developing a space ship capable of blasting off like a rocket, orbiting the earth like a satellite and landing like a conventional airplane, the project is still far from solving the control problems. Air Force expects flight tests with the experimental X-15 to shed some light. Both prime contractors have been lining up top teammates. With Martin are Goodyear Aircraft, Bell Aircraft and Minneapolis-Honeywell. Boeing's partners are Chance-Vought Aircraft, General Electric, Aero-Jet General and Ramo-Wooldridge.

•

Inertial guidance will play a major role in improving safety in future transportation, according to MIT's Instrumentation Laboratory Chief Dr. C. Stark Draper. He sees the inertial principle providing second to second information on position and velocity. Even low performance inertial instruments, says Draper, would require no more than infrequent radio monitoring by digital signals to provide automatic flight track control.

Small...sensitive...high-speed

POLAR RELAY

for billions of maintenance-free operations



New Type 204 Series PTW Polar Relay has octal plug mounting for universal use. Height, $2\frac{13}{16}$" plus $\frac{41}{64}$" projection of mounting plug; width, $2\frac{9}{32}$" x $1\frac{11}{16}$". Type 202 has standard banana-type terminals; Type 203 has pin-type terminals.

HERE'S A 2-position Polar Relay that can be depended upon for switching a single circuit at high speeds through billions of operations—*without readjustment.*

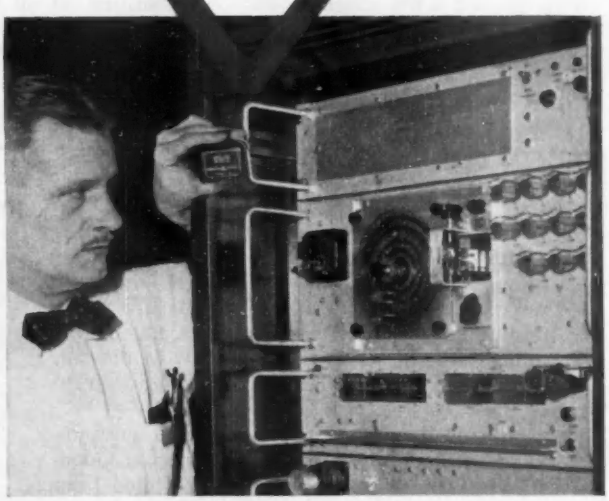
Substantially smaller than other polar relays, the Automatic Electric Series PTW is designed for telegraph and teleprinter circuits—teletypewriter switching—teletypewriter repeater circuits—plus other industrial and military applications. Type 203 is completely interchangeable with Western Electric 255A relays.

Check these unique advantages

Because of its simple design and compact construction, the PTW costs substantially less than other relays you may have been using. It delivers lightning response (travel time as little as 0.7 of a millisecond!). And its design assures adjustments that stay put practically forever.

Series PTW Polar Relays are available with various type terminals to fit both new and existing applications—including surface mounting of Type 202 in replacement of Western Union Type 17 relay.

For full information, call or write Automatic Electric Sales Corporation, Northlake, Illinois. *In Canada:* Automatic Electric Sales (Canada) Ltd., Toronto. Offices in principal cities.



Automatic Electric Polar Relay is used in selector cabinet of Teleregister Corp. stock-quotation system. Teleregister design engineer, Jim Hartelius, shows how snap-on cover can be removed for visual inspection. He reports " . . . complete reliability . . . almost infinite life . . . virtually never gets out of adjustment."

AUTOMATIC ELECTRIC

Northlake, Illinois • Subsidiary of **GENERAL TELEPHONE**

Process Control Stars at ACHEMA

ACHEMA, the European Chemical Engineering Exhibition & Congress, is usually dominated by chemical equipment displays. This year's show, at Frankfurt-on-the-Main, was somewhat a surprise. Over 10 percent of the exhibition space was taken by almost 100 manufacturers of instruments and control gear. And some of the biggest news at ACHEMA developed in the control field.

For example, the appearance of Agfa as a control manufacturer jolted a lot of visitors. The Bayer Farbenfabriken giant has always been a big buyer of instrumentation and control. But it was completely unexpected to find the company offering a line of specialized instruments made in the Agfa-Physik plant in Munich.

American control visitors to the show got a first-hand review of German techniques. Although some U.S. visitors felt that German manufacturers trail American counterparts by three to five years, the Germans claim their instruments will cover any requirements. Probably the true status lies somewhere between the two views. Progress is advanced in some areas; spotty in others. Some typical trends:

- ▶ widespread development of nonlinear controllers
- ▶ emphasis on electropneumatic systems
- ▶ efforts to miniaturize panel instruments to a standard 144 x 144 mm (5.66 x 5.66 in.)
- ▶ combining electronic tubes with magnetics in controllers to cash in on magnetic amplifier experience

The most apparent failing of German equipment is in the construction. A German device will take up more boxes than a similar one made in the U.S. Mechanical techniques are frequently used, even though they make the instrument awkwardly big. And there's still no sign of a combined recorder-controller.

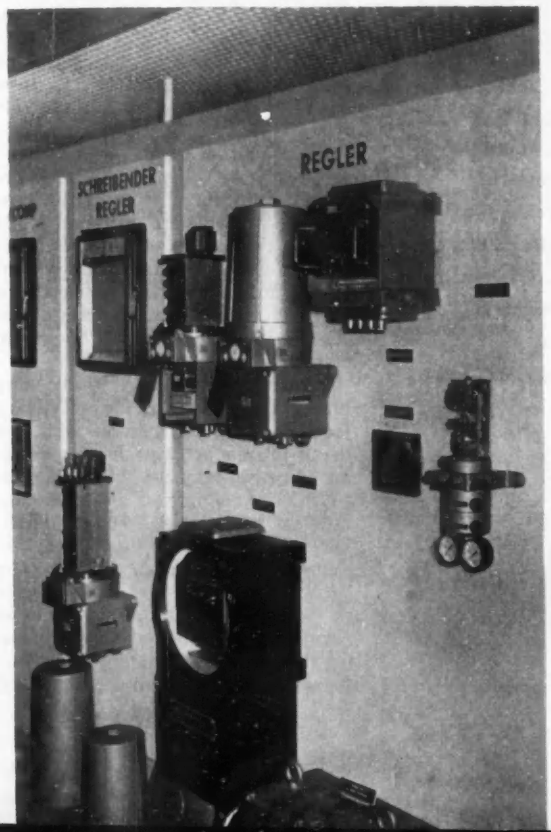
German engineers blame smaller markets for these deficiencies. They say that development money is scarce. Explaining the lack of a recorder-controller, they say that separating the units allows them to concentrate efforts on the single unit they want to improve, instead of a combination.



• Nonlinear systems emerge—Very obvious at the show was the emphasis on nonlinear controllers. Four systems were displayed; others are being developed and studied.

Farthest along is the Siemens & Halske Telepneu-Teleperm system. Fully interchangeable units permit selection of a pneumatic system, any combination of electropneumatic sys-

H&B's nonlinear controller **(page 24)**



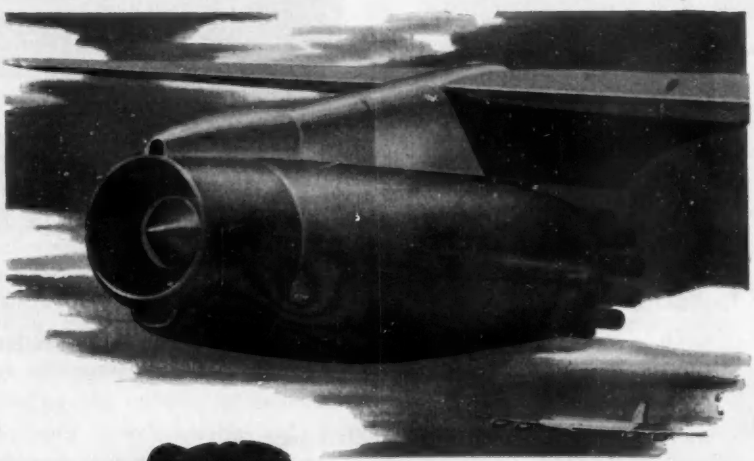
V&H's mixing control **(page 26)**

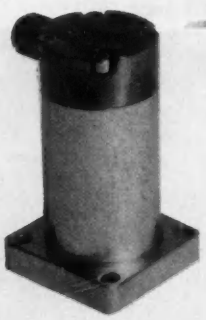


designed for jet engines

...CEC's economical vibration pickups

Wherever vibration is present—on jet engines, machinery, motors, or generators—CEC's new line of low-cost vibration pickups find ready application. Featuring *constant damping* over the operating temperature range of −65°F to +500°F, the omnidirectional 4-123 and its horizontal and vertical counterparts (4-121 and 4-122) perform with precision in oily or corrosive atmospheres. Sand, dust, or fungus cannot penetrate their hermetically-sealed interiors.





The 4-123, with its 45-2000 cps operating range, is ideal for jet-engine monitoring where the lowest frequency encountered is approximately 50 cycles. The 4-121 and 4-122 monitor turboprop vibrations in the range of 15 cps to 2000 cps. Each type weighs only 4.25 ounces including connector. For additional information, call your nearest CEC sales and service office, or write for Bulletin CEC 1596-X4.

Transducer Division CEC

Consolidated Electrodynamics

300 North Sierra Madre Villa, Pasadena, California

RECOGNIZED LEADER IN GALVANOMETERS—TELEMETRY, PRESSURE AND VIBRATION INSTRUMENTATION

WHAT'S NEW

tems, and the fully electric Teleperm system.

Heart of Teleperm is an all magnetic controller with pulse duration and frequency modulation feedback to provide proportional and integral action. After a secret two-year trial period in Germany, the system is being installed in the German-built steel mills at Rourkalla, India.

• **Seimens controller**—Designed on a building block principle, the controller consists of three units separated into measurement, feedback and control sections. The measuring unit has potentiometric or bridge inputs.

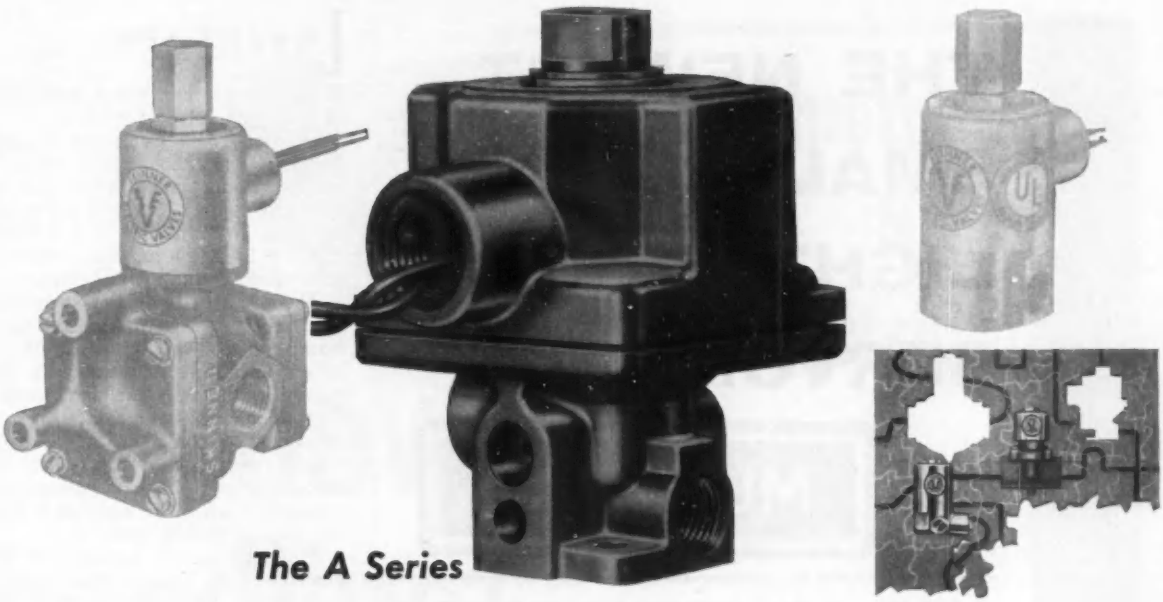
In the control unit, after amplification by an input magamp, the error signal operates two push-pull monostable magamps. Output relays in these magamps provide directional information to the actuator. From each relay, feedback is taken through two separate CR networks to the input magamp. When the error signal is nulled through the feedback path the relay opens and, as the CR network discharges, the monostable magamp cuts in again to make the next pulse.

Pulse length and duration are directly proportional to the error signal magnitude, thus giving a proportional band for the controller that decreases with large error signals. For process times greater than 10 sec an additional thermal feedback unit extends feedback time up to 8 min.

• **Schoppe & Faeser**—In another system, Schoppe & Faeser of Minden uses tubes instead of magamps. Impulse feedback is taken directly from the actuator instead of the amplifier relays.

An induction motor and eddy current disc are coupled to a special synchro transmitter to supply an integral time range from 1 sec up to 24 hours. To do this, damping magnet position is varied along with the input voltage to the motor. The S&F system uses a 50-mv ac or dc input, conversion being achieved by a plug-in dc-to-ac transistor modulator.

• **Joens' controller**—A third nonlinear controller is built by W. H. Joens of Dusseldorf. In this unit, the on-off relay is actuated by the damping of a series-resonant circuit attached to the set-pointer by an aluminum vane on the measured value pointer. Feedback elements, both thermal and electronic, give integrating times up to 45 min with derivative times of 5 min; the proportional band extends from 0-300 percent. Following the standard German practice, the Joens controller is completely housed



The A Series

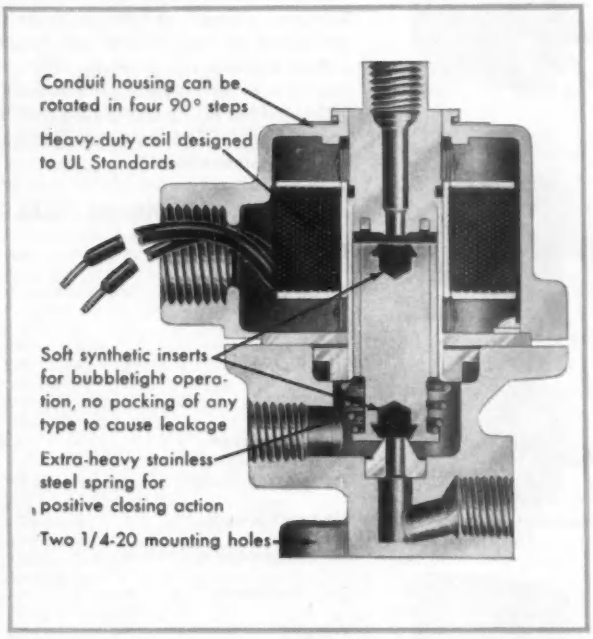
NEW— three-way Skinner Valve line for medium-size cylinders

This new A Series valve line bridges the gap between the famous V5 line used with small cylinders and the reliable M3 line used with large cylinders. The design of this new line permits economical and efficient operation of medium-size cylinders as well as faster operation of smaller cylinders where increased cycling speed is a necessity.

The first of the A Series line is a 3-way normally closed valve with a $\frac{5}{32}$" orifice and $\frac{1}{4}$" NPT ports, and a pressure rating of 125 PSI. It is designed for use with such media as oil, air and inert gases.

Despite the increase in capacity, this new valve is light in weight (only 3 pounds) and compact ($3\frac{7}{8}$" high and $2\frac{5}{8}$" square). The body and mounting are non-corrosive zinc and the internal parts are stainless steel. The plunger is spring-loaded and direct-acting, and the valve can be mounted in any position. Soft synthetic inserts are used, assuring bubbletight operation and long, trouble-free life.

For additional information, options and specifications, call the Skinner Representative or Distributor nearest you – he's listed in the Yellow Pages. Or write us at the address below, Dept. 348.



SKINNER ELECTRIC VALVES

THE CREST OF QUALITY

SKINNER ELECTRIC VALVE DIVISION

NEW BRITAIN CONNECTICUT

105 EDGEWOOD AVENUE

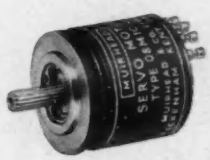
THE NEWEST SMALLEST LIGHTEST SERVOMOTOR

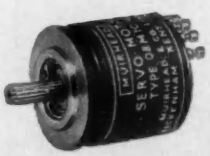
by MUIRHEAD

SIZE 08 SERVOMOTOR









To meet the increasing demand for low weight small size components, Muirhead have produced the size 08 servomotor. Conforming to the standard 08 frame, this miniature motor has an overall diameter of 0·750 in., a length of 0·963 in. from the front face of the spigot to the ends of the connexion tags, and a shaft extension of 0·156 in. The shaft is splined in the form of an involute pinion of 13 teeth 120 D.P. 0·1245/0·1240 in. O.D., 0·1083/0·1078 in P.C.D. 20° pressure angle. The body material is black dichromate finished stainless steel.

TECHNICAL DATA

Type Number	08M10A1
Supply	26V 400c/s
Stall Current	77mA
Stall Power	1·7W
Stall Torque	0·1 oz. in.
Stall Impedance	286 + j 184 ohms
Stall Power Factor	0·85
No Load Speed	6500 rev/min.
Rotor Moment of Inertia	0·0026 oz. in²
D.C. Resistance	230 ohms
Weight	1·0 oz
Temperature rise of motor stalled in free air unmounted	65°C.

MUIRHEAD INSTRUMENTS INC., 677 Fifth Ave., New York 22, N.Y., U.S.A.
MURRAY HILL 8-1633

MUIRHEAD INSTRUMENTS LIMITED, Stratford, Ontario, Canada
TELEPHONE 3717

MUIRHEAD & CO., LIMITED, Beckenham, Kent, England
BECKENHAM 4888

337/3

WHAT'S NEW

in the miniature standard panel size of 144 x 144 mm (5.6 x 5.6 in.).

Only one firm has made its controller smaller. Schoppe & Faeser's new electropneumatic system fits in a 96 x 96 mm (3.78 x 3.78 in.) panel for their PI controller; 72 x 72 mm (2.83 x 2.83 in.) for the associated unit—set-point and manual controls.

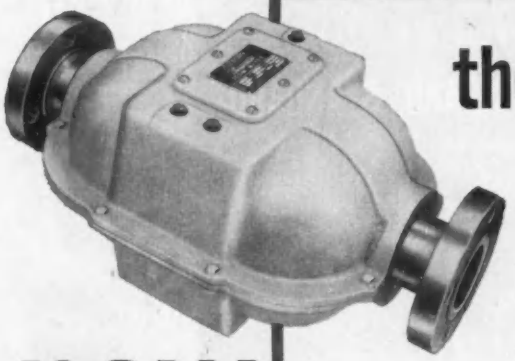
The separation of the controller from its controls illustrates the German trend to divide the panel display into at least three different units, the controller, the set-point, and manual controls; and give the indicating system its own recorder. In the set-point control, single knob operation for automatic and manual settings appears unknown; all systems use a separate manual control knob.

The S&F system operates on the NAMUR (the German control users association) standard transmission level of 12 volts, 50 cps. Differential transformers are used throughout to convert temperature, pressure and flow. Output of the controller is a 0-3 ma signal for electropneumatic valve operation. Tube amplifiers give a proportional band from 2 percent to infinity while Miller integrators give an integral time up to 2 min.

• **H&B's simplified design**—A fourth nonlinear controller is the Hartmann & Braun developmental model. Galvanometric amplification of the signal operates directional relays by interruption of a light beam on photocells. Feedback is obtained through a single CR network from a separate stabilized supply which is reversed in polarity in synchronism with the directional relays. In this way full PID action is obtained with a proportional band of 0-100 percent; integral time ranges from 0.5-20 min; and derivative time up to 5 min is obtained.

Complementary to this in the H&B line is the 0-20-ma dc UMC system made up of a proportioner, a timing unit and stabilized power supply.

• **New instruments**—In the instrument field much show interest was aroused by the newly announced Agfa rotating viscometer, covering a range of 10^{-1} to 10^{-5} poise. In the measuring head are two cups, the outer rotating with a servo system that maintains speed accuracy over a range of 0.01-10 rpm. Movement of the inner cup displaces a torsion bar to which is attached a measuring beam operating between inductive pickoffs. A direct reading bridge connected to the pickoffs measures the shearing stress of the fluid between 10 and 10^{6} dynes/cm². A built-in resistance thermometer allows viscosity measure-



the meter with NO flow restrictions

now handling all these difficult liquids

Foxboro's first Magnetic Flow Meter went "on stream" in 1954. Today, this new-type meter has gained industry-wide application for precise, continuous measurement of difficult process liquids.

The Magnetic Flow Meter is installed as simply as a length of pipe. No seals, purges, meter runs, or straightening vanes are required. It connects by standard electric cable to remote Dynalog Electronic Recorder. Over-all accuracy of the system is ±1%. And the meter even measures reversing flows.

With easy-to-measure liquids, or with tough ones like those listed below, the performance-proved Foxboro Magnetic Flow Meter provides flow measurement with no line restrictions. For complete details, write today for Bulletin 20-14B. **The Foxboro Company, 368 Norfolk St., Foxboro, Mass.**

CHEMICALS
ammonium nitrate solution
phosphate slurry
rayon viscose
magnesium carbonate slurry
phosphoric acid slurry
detergent concentrate
rosin size
starch solution
rubber copolymer
liquid latex
soda ash
sulphuric acid
70% sodium hydroxide
soap flow
styrol
magnesium hydrate

FOOD
beer
grape juice
apple juice
pineapple juice
tomato juice
milk
starch slurry
sugar syrup
coffee slurry
molasses

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all types of pulp stock
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thickener mud
cement slurry
flue dust slurry
acid wastes

OIL INDUSTRIES
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ethenol extract
scrubber recycle water
urea solution
nitrate solution
spent acid
sodium silicate & water
sodium chloride brine
tar-sand slurry

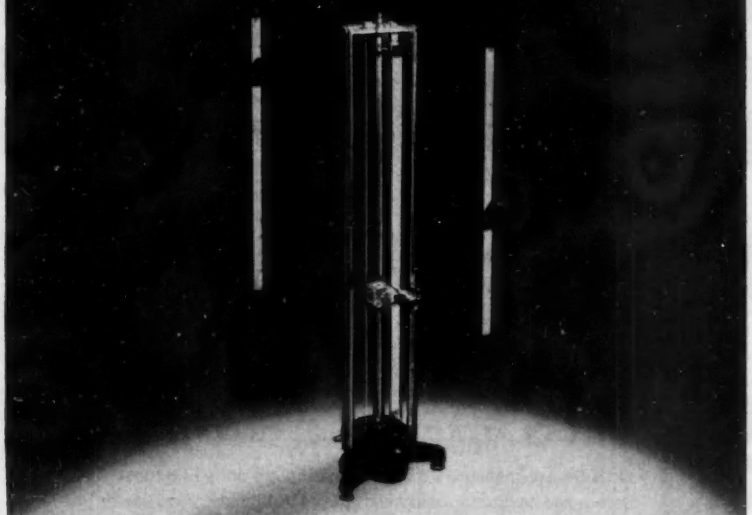
METER SIZES RANGE FROM 3/16 INCH TO OVER 6 FEET PIPE DIAMETER

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MAGNETIC FLOW METERS

Something Special

IN A STANDARD STANDARD



For those jobs, only a manometer can do . . .

When you're faced with precision calibration, production checks of other accurate instruments, or any kind of laboratory pressure work . . . in fact, any time you need better than 0.1% accuracy that's the time to add a W&T precision mercurial manometer.

Rapid readout with the magnified magnetic vernier makes exact pressure readings easy. All 'round leveling, temperature compensation and gravity correction are included, of course.

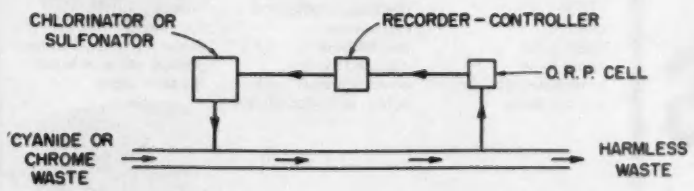
range: 0 to 31.50 inches Hg., or any other desired pressure unit of equivalent range.

accuracy: 1/5000 over full scale.

For full information on all models of W & T precision mercurial manometers, write Dept. A-121.00.

WALLACE & TIERNAN INCORPORATED

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An oxidation-reduction potential cell, monitoring treated waste provides the signal for recording and controlling treatment chemical quantities in a typical W&T waste treatment system.

For Full information on Industrial Waste treatment write Dept. I-66.28

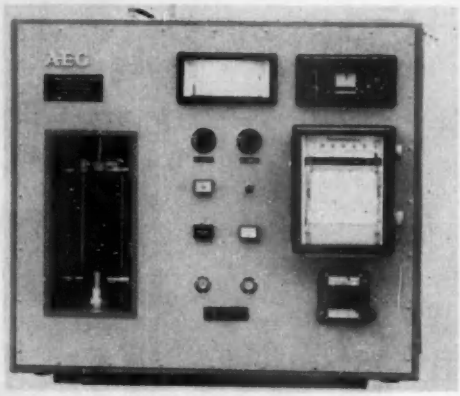
WALLACE & TIERNAN INCORPORATED

25 MAIN STREET, BELLEVILLE 9, NEW JERSEY

In Canada, Wallace & Tiernan, Ltd. — Toronto

WHAT'S NEW

. . . Germany's first automatic distillation unit with magnetic amplifier control . . .



ments to be made over a range of 50 deg C.

Also in the viscosity field–but concentrating on control–is Askania-Werke of Berlin. This control system, priced around $600, uses the capillary method. But the capillary tube is mounted concentrically within the main flow line; a separate flow controller maintains constant flow through the tube. With the capillary as an integral part of the main line, the temperature of the sample and the main flow are the same.

• **Mixing controls**–An interesting device shown by Voigt & Haeffner, Frankfurt, controls mixing of predetermined liquid quantities. It also programs temperature and vacuum in the mixing kiln and actuates final drawoff. A plug-in board programs up to 14 variables, each with 32 steps. Plug-in contacts operate simple relay circuits, stepping switches and induction motor timers to provide variable time delays between steps from 1 sec up to 20 min.

Similar in appearance to a plug-board programmer was the AEG statistical recorder. In this device, the input voltage is balanced in a self-balancing bridge, then classified into 18 categories, each a percentage of a predetermined set value.

Also shown by AEG was the first German automatic distiller with automatic printout of the boiling curve. Based on the ASTM D86 specification, the equipment uses magnetic amplifiers to control the heating power to the retort. A photo-resistor mounted on a motor-driven leadscrew measures level of the distillate. Distillate rate is determined by a potentiometer pick-off from the leadscrew.

–Derek Barlow



an Epsco system controls test data

at REPUBLIC AVIATION

In this automatic, multi-channel data acquisition and computer linkage system, the processing of data has been developed from a *handling* function to the level of true data *control*. Installed in the Engineering Research Laboratories at Republic Aviation Corporation, Farmingdale, Long Island, this Epsco system . . .

- excites and processes structural analysis data from 200 low-level strain gage sources
- sequences, amplifies, samples, and converts this data into digital form at rates up to 4000 conversions per second
- prepares magnetic tape for direct entry into an IBM 704 computer

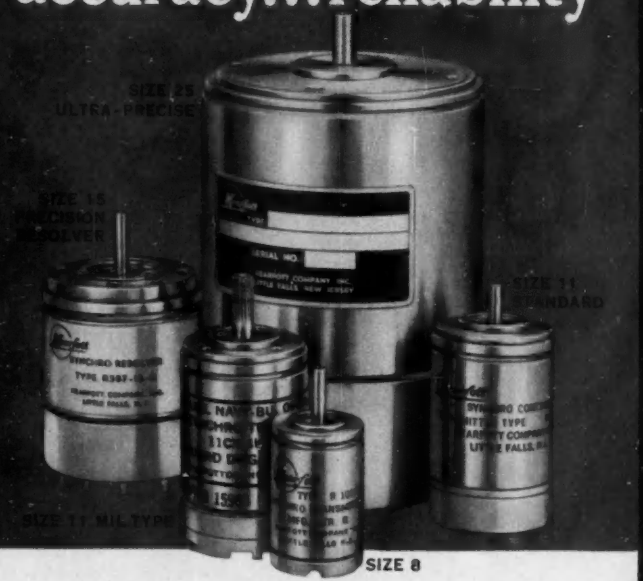
Assembled from production-engineered Epsco system building block modules — for economy, quick delivery, minimum maintenance and expandibility — this system is being used initially to control data from air frame structural tests. Later it will be expanded to control wind tunnel test data. For complete engineering information write for Systems Design Bulletin ES-004, Commercial Systems Division, Epsco, Inc., 588 Commonwealth Avenue, Boston, Mass.

Epsco - First in data control

Epsco, Incorporated, 588 Commonwealth Ave., Boston 15, Mass. *For service in the West:* Epsco Service Corp. of California, 1722 Westwood Blvd., Los Angeles 24, California

Synchros...another Kearfott capability

accuracy...reliability



SIZE 8

SYNCHROS FOR EVERY APPLICATION

Kearfott offers the widest range of synchros in the industry. Ruggedly constructed of corrosion-resistant materials, they give unequalled performance under every environmental condition. For best characteristics and reliability, specify Kearfott for all your synchro requirements. Here are a few typical models:

Size 8: .750″ x 1.240″. 1.75 oz. −54C to +125C. Available as transmitter, control transformer, resolver, and differential. Max. error from EZ: 10, 7 and 5 minutes.

Size 11 Standard: 1.062″x1.766″. 4 oz. −54C to +125C. Available as transmitter, control transformer, repeater, resolver and differential for 26v and 115v applications. Max. error from EZ: 10,7 and 5 minutes standard, 3 minutes in 4-wire configurations.

Size 11 MIL Type: Dimensions and applications same as above. Meets Bu. Ord. configurations: max. error from EZ: 7 minutes.

Size 15 Precision Resolver (R587): With compensating network and transistorized booster amplifier, provides 1:1 transformation ratio, 0° phase shift. Max. error from EZ: 5 minutes.

Size 25 Ultra-Precise: 2.478″ x 3.187″. 45 oz. Available as transmitter, differential, and control transformer. Max. error from EZ: 20 seconds arc.

***Engineers:** Kearfott offers challenging opportunities in advanced component and system developments.*

Kearfott

GENERAL PRECISION EQUIPMENT CORPORATION GPE

KEARFOTT COMPANY, INC., Little Falls, N. J.

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WHAT'S NEW

Automation Show Shrinks

The 1958 exhibition at New York's Coliseum failed to draw exhibitors or attendance.

To many control salesmen who are finding 1958 a disappointing year, the 1958 Automation Congress & Exposition fit right in. It was the biggest disappointment of the year so far. For one thing, a surprisingly small number of exhibitors showed up. Many of the big-name absentees apparently canceled their space before show time; but others just failed to arrive, leaving empty booths to mock the show. Attendance was sparse throughout the entire week; one estimate: only 8,000 (not counting exhibitor personnel), less than one-third of the 25,000 expected by the show's management. And in most of the booths there was little new for visitors to see.

One of the few unusual events at the show was an exhibit of Russian instruments, manned by Russian control engineers. (For a talk with the Russians, see page 30). This was probably the first such display held in the United States since the Soviet exhibition at the 1939 New York World's Fair. But even it was somewhat disappointing. There was little unusual and nothing spectacular in the Russian booth, primarily a display of conventional instruments like an infrared analyzer, an ultraviolet analyzer, an optical pyrometer, a heat-flow meter, and electrical measuring instruments. Most could have been mistaken for U.S. instruments if the Russian nameplate were removed.

With their ill-fitting suits, uncomfortable shoes and initial shyness, the Russians were undoubtedly the hit of the show. They easily eclipsed the few innovations displayed by other exhibitors. But among the new items:

- mechanical amplifiers were displayed for the first time by Seneca Falls Machine Co. and Universal Match Corp. The latter machine is capable of a gain of 500 to 1.
- prototype for a new mechanical digital readout for use with strain gages was in the Dynametrics booth.
- An extremum controller for the process industries was displayed by Quarie Controllers.
- A new punched tape block reader for numerical controlled systems was shown by Wang Laboratories, Inc. It can read up to 10 frames per sec., 12, 16 or 20 lines per reading.



Cleveland Speed Variator applies power to power-steering assembly line

Providing variable speeds to the final inspection and assembly conveyer on a power steering gear generator line is a Cleveland Speed Variator. This Cleveland was chosen for its infinitely variable speeds which enable management to obtain a desired number of units per day by merely selecting a suitable conveyer output speed.

One of 22 Variators in the plant, this installation of a Cleveland Speed Variator has a side benefit to labor and management by eliminating problems stemming from disputed conveyer speeds.

Other advantages of Cleveland Speed Variators include: 1. Clockwise or counterclockwise input speeds to 1800 rpm; 2. Constant horsepower output over a 9:1 range, or constant output torque over a 6:1 range; 3. Rapid response to speed changes, precise adjustments, accurate adherence to settings; 4. Long life with minimum maintenance; 5. Ample bearing support for overhung pulleys on either input or output shafts; 6. Compact design.

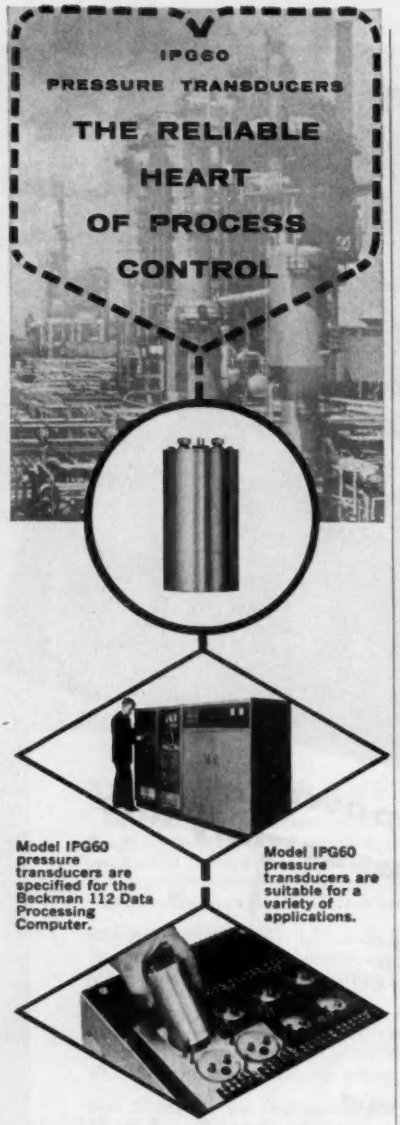
Write today for illustrated Bulletin K-200 for complete specifications, sectional drawings and rating tables on the full line of Cleveland Speed Variators.

The Cleveland Worm & Gear Company, Speed Variator Division, 3260 East 80th Street, Cleveland 4, Ohio.

Sales representatives in all major industrial markets.
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CLEVELAND SPEED VARIATOR



The evolution of industry toward automation has created a demand for precision data handling systems such as the Beckman 112 Data Processing Computer. Statham Model IPG60 pressure transducers are specified in this system, providing basic information signals which are accurate within ±¼%. Complete data on the Model IPG60, or information on other Statham instruments, are available upon request.

RANGE: 0 to +15 psig.
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OUTPUT: Approximately 35 mv. full scale at 14 V. excitation
NON-LINEARITY & HYSTERESIS: Not more than ±0.25% of full scale

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A Talk with the Russians

During the Automation Show, a Control Engineering editor interviewed five visiting Russian engineers, each a specialist in a different aspect of control technology. His report sheds some more light on the status of Soviet control.

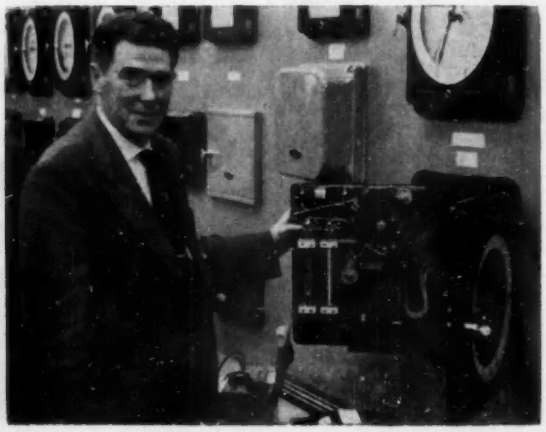
Nikolai N. Elshin is chief of automation and mechanization in the USSR's Ministry of Chemistry. His main job: applying instrumentation to boost productivity in the chemical process industries. Amiable and soft-spoken, engineer Elshin speaks fluent English, knows the U.S. process industries well as a result of two years spent with Amtorg (The Russian Trading Co.) in New York.

Today Elshin feels Soviet technology in process control is almost on a par with that in the U.S. He says Russian plants are using the same kinds of instruments and techniques—infrared, ultraviolet, gas chromotagraphy, etc.—in production as are U.S. companies; Russian engineers are evaluating data loggers and information systems in their plants; and research laboratories in technical institutes are studying new techniques. Two areas still in the laboratory stage: the use of nuclear magnetic resonance as an analysis technique and computing-control. There is, says Elshin, at least one application in a petroleum refinery of closed loop control using an infrared on-stream analyzer.

• **Instrument design.** One of the technical divisions in Elshin's group is the Technical Bureau of Automation in Chemistry which designs and develops most of the instruments used in Russian chemical plants; it produces some of them, too. Chief Engineer Nicolai Festa is currently responsible for design. Although Festa speaks no English, he can read and write it. Through an interpreter he said that Russian instrument designs were particularly rugged, built to withstand the abuse dished out by unskilled production workers. Pneumatic instruments, says Festa, are used almost exclusively in Russian chemical plants. The main reason, according to the instrument designer, is a strong stand by Russia's National Fire Dept., which has opposed the use of electronic process control in the chemical industries because of possible explosion and fire hazards.

Festa's latest project has been the design of an extremum controller, a pneumatic analog device. He says there are at least 10 installations of this controller already in USSR distillation and catalyzation units.

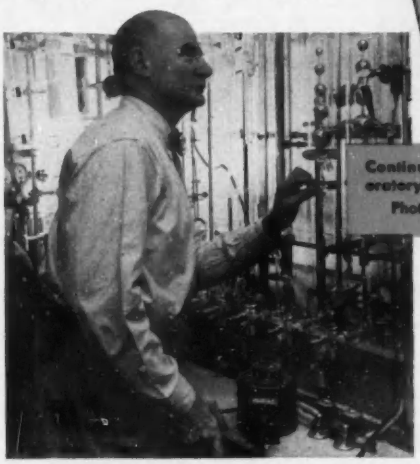
I asked Festa how the men who operate chemical plants learn about new instrument designs. "Through monthly information bulletins," he



Instrument designer Nicolai Festa shows off a Russian infrared analyzer, designed by his group.

- Good Regulation
- Smooth Control
- Long Life
- High Efficiency
- Operation from 50 to 400 Cycles

Variac - THE CONTROL THAT SOLVES THESE MANY PROBLEMS



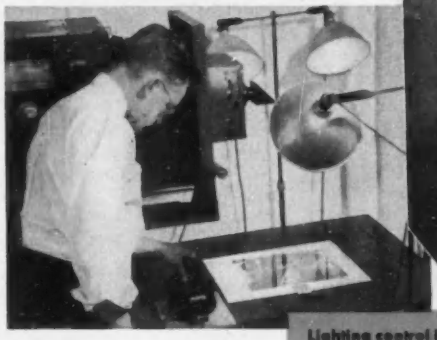
Continuously-adjustable a-c voltage for laboratory research and development work.
Photo Courtesy Bell Telephone Laboratories



Control of electric heaters and ovens in laboratories and pilot plants.
Radiation Counter Laboratories



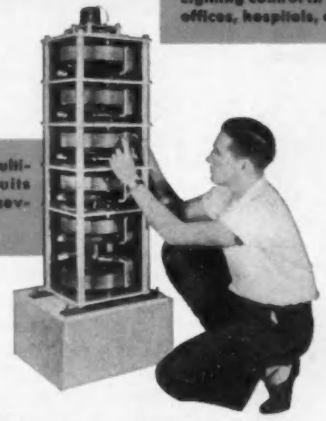
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WHAT'S NEW

answered. Each month design and application information on new available instruments is published and distributed widely to all plants. One problem with the system, Festa hinted, is that a plant manager receives a tremendous number of bulletins each month because each type of product has its own publication.

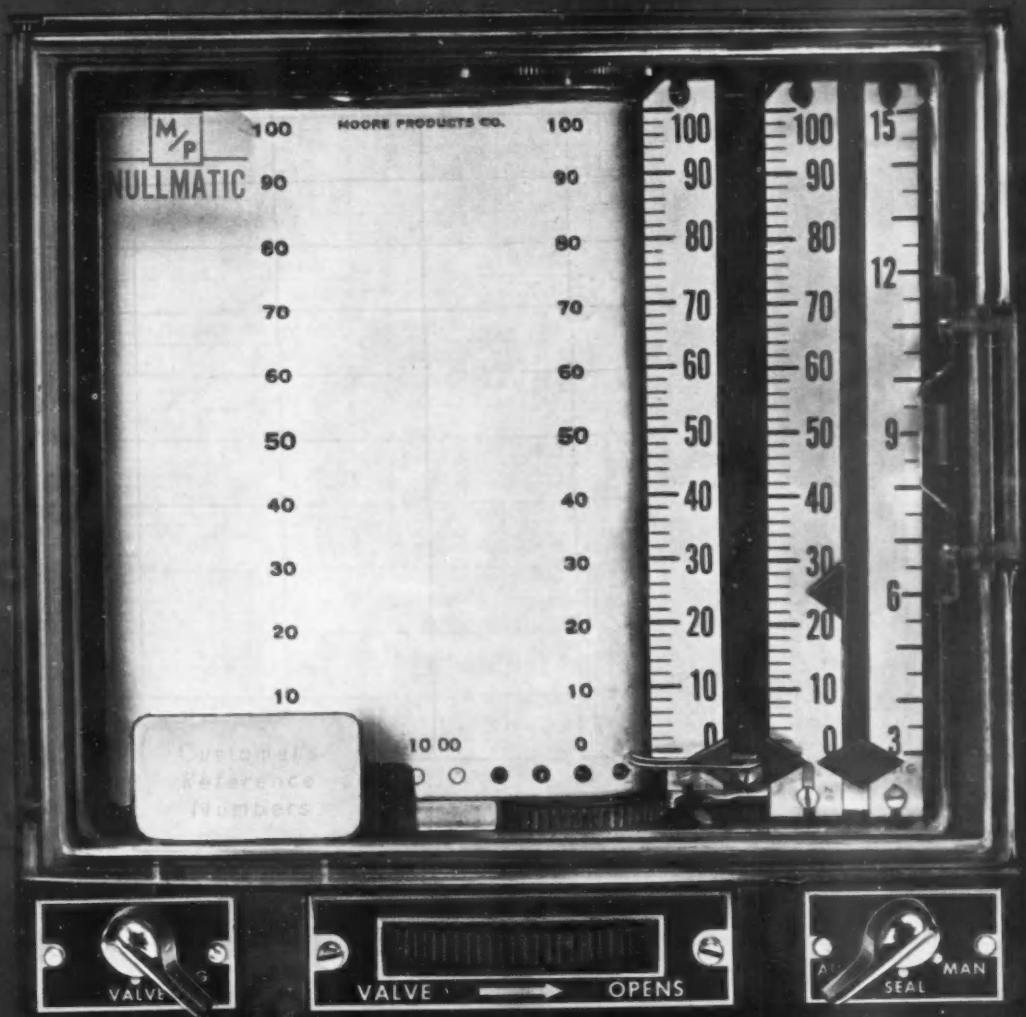
• **Soviet steel hangers**—Lev A. Charikov, a specialist in steel mill control, also speaks excellent English because of an assignment with Amtorg in New York from 1946 to 1948. Charikov is quick to admit that the use of automatic controls in Russian steel applications probably lags behind U.S. applications. For one thing Soviet hunger for steel is so keen that the only factor ever considered is how to increase productivity. And the Russians have been unable to come up with automatic controls that would increase production.

One example Charikov cites is the use of punched card control of reversing mills. He knows there are several applications in the U.S., but only a single experimental one in the Soviet Union—on a small mill rolling sheet for razor blades in Leningrad. The reason, he says, is that Russian rolling mills are set to produce sheet at twice the rate of U.S. mills. The way the Russians do this is to use two operators who continually change screw down while the billet is being rolled (instead of waiting for the billet to finish a pass). Applying punch card control to mills operated like this, he says, only cuts their productivity. The Leningrad experiment, for example, resulted in a 7 percent reduction in productivity. So punch card programs for reversing mills are being studied in laboratories but not used in production facilities in Russia.

• **Checking surface conditions**—The increased productivity of Russian rolling mills, Charikov pointed out, has its disadvantages, too. For one thing it's hard to hold tolerances and surface condition under these rolling conditions. That means close inspection of sheet from the mill is required. Engineer Charikov estimates that 40 percent of all steel production labor goes into checking dimensions, inspecting surface conditions, and handling the finished product during these operations. One of the big technological efforts in the USSR steel industry is aimed at making some of this work automatic.

Still another important effort, says Charikov, is attempting to eliminate the human operator on the skip hoist of blast furnaces. The Russians have

Announcing . . .



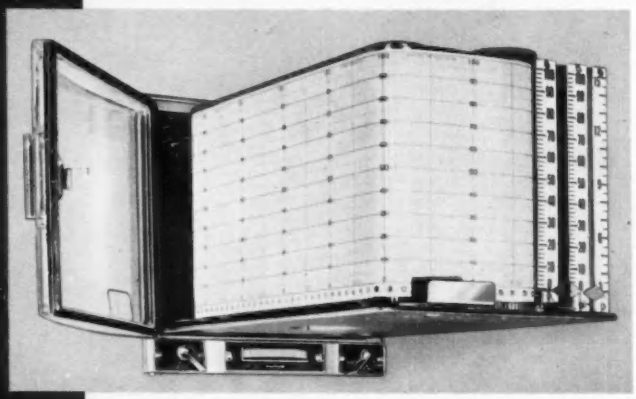
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M/P Recording Controller

- Four-Inch Chart
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- Leak-Proof Switching
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See it at the Moore Products booth—I. S. A. Show

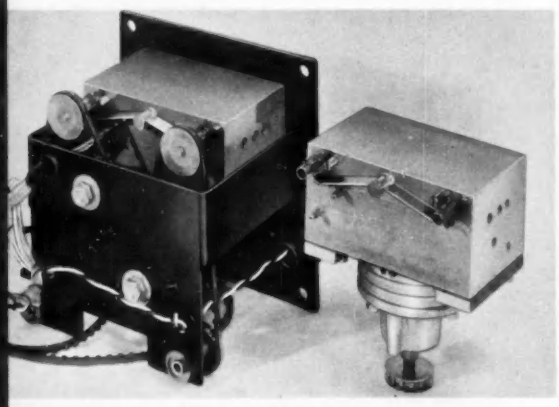
—more features on the reverse side ➡

Features of the new Moore M/P Recording Controllers



Maximum Readability: The four-inch wide, 31-day charts provide strong contrast for the pen record. Figures are bold. Graduations are printed with precision. Drawing out the chassis to its stop (as shown above) permits accurate reading of a 12-hour record—without touching the chart.

"Fail-Safe" Feature: Because of the "umbilical cord" method of connection and the self-sealing terminal block, it is possible to withdraw the chassis or to replace it without disturbing the process. Moore engineers have included an unusual provision by which Controller upset is negligible (less than 1%) even if the connections are accidentally broken.



Leak-Proof Switching: (above) These Recording Controllers are new—but they use the same transfer and by-pass switch blocks that have been standard in all Moore M/P Indicating Stations for the past five years. The special "O"-ring seals in these switches assure leak-proof operation. (Tests prove their performance for over 1,000,000 cycles, without leakage.) Thousands of indicating stations in the field confirm the dependability of these switches.

A Complete Line: Twenty-nine models cover practically all requirements in single-pen and two-pen instruments—for automatic, cascade, and manual control systems. All models are interchangeable in 5 7/16 x 5 11/16 panel cut-outs with Moore M/P Indicating Stations. All standard plug-in NULLMATIC Controllers fit all manifold recorders.

Positive-Acting Precision Adjustments: The control-point-regulator adjustment and the switches both operate with standard timing-belts. Smooth and positive action, freedom from corrosion, and long life result. Adjustments are accessible without opening the door.

NEW! Simplified, Single-Station Cascade Recording Controller

This new design introduces the first straightforward "bumpless" switching between Cascade, Automatic, and Manual. Only two steps are required to obtain fool-proof transfer from one position to another. Saves panel space and investment in two stations. Saves time in switching and eliminates errors.

"Bumpless" Transfer: Operators know the advantages of Moore manual-automatic switching from using M/P Indicating Stations. The same procedure is used in these new recording instruments. Control-point and valve pressures are measured by the same element, so that duplication is assured. A manually adjustable Memory Pointer is available as an accessory.

"Ni-Span" Elements: These large elements are practically uneffected by ambient-temperature changes. Process value, control-point setting, and valve position are all indicated as live pressures.

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already developed a closed-loop control system that uses a computer. But Charikov feels it is too complex, too hard to keep working. He would like to see a simpler blast furnace control. To Russian steelmen, the blast furnace is their biggest bottleneck.

• **Machine tool control**—The Russians seem well advanced in the field of numerical control for machine tools. Professor Anatoli Gavrilov, chairman, Machine Tool & Instrument Building at the Moscow Machine Building Institute and president of the Scientific Institute of Instruments, is currently editing a publication on numerical control (The title: Automation of Industry Processes in Instrumentation [Precise Machinery]).

Design of numerical control, says Professor Gavrilov, is accomplished at technical institutes. Because there are a large number of them interested in machine tools, there are a large number of numerical control designs, both continuous contouring and point-to-point systems. Gavrilov says the systems use a wide variety of inputs: punched cards, punched tape or magnetic tape, depending on the application and accuracy required.

A considerable number of the numerically-controlled tools have moved from the institutes into production plants, says Gavrilov. The control has been applied to lathes, grinding machines, punch presses and milling machines. Industries using numerical control in production: automotive, machine tool building, and aircraft fabrication. The major limitation to present numerical control, says the Moscow professor, is the overall accuracy of the system. He believes Russian systems (and he says U.S. systems have the same limitation) still do not offer the degree of accuracy Russian production men want.

• **Advances in computers**—The advanced work in all fields of control technology lead to the assumption that Russian computer technology must also be pretty well advanced. And it is. Computer specialist Valentin Ushakov said, through an interpreter, that a wide variety of digital and analog machines have been developed in the Soviet Union. For example, on the digital side the Type URAL M-3 is a machine about equivalent to the U.S. IBM 650. The STRELA (meaning arrow) has about the same capabilities as the IBM 704. Both of these are in production. A new expanded digital machine—BECM (Big Electronic Calculating Machine)—has been developed but is

14321

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26-volt models (torque at stall .25 oz. in., power input 2.3 watts)	Weight oz.	Length in.	Rotor Inertia gm. cm.²	Acceleration at Stall rad/sec²
8 SM 420 servomotor	1.1	.840	.1	170,000
8 MG 420/410 servomotor-rate generator	1.9	1.350	.16	110,000
8 VM 420 velocity-damped servomotor	1.9	1.305	.24	73,000
8 IM 420 inertia-damped servomotor	2.0	1.355	.24	73,500
115-volt models (torque at stall .33 oz. in., power input 2.9 watts)				
8 SM 460 servomotor	1.6	1.165	.2	115,000
8 VM 460 velocity-damped servomotor	2.4	1.720	.34	68,000
8 IM 460 inertia-damped servomotor	2.5	1.680	.34	68,500

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WHAT'S NEW

not yet in production. Its capabilities surpass the IBM 704, says Ushakov.

In the analog field there's a lot of activity, too. Large-scale production is under way on the MH-10, an all-transistorized unit with crystal transducers and diodes. In addition, the Russians have built many special-purpose analog machines. Samples: a machineability computer, a chemical process simulator, a steel mill analyzer.

Of all developments under way, Ushakov seemed proudest of Russian accomplishments with transistors. He predicted the biggest application for computers would be in control, using transistorized equipment.

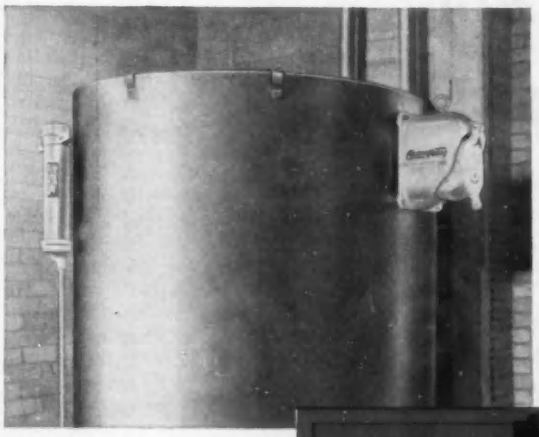
• **A U.S. editor's impression**—Talking with the Russians left some positive impressions about the state of Soviet control engineering and control engineers. First, it is hard not to be impressed by their apparent competence and confidence. They seem to know exactly what they are doing and are proud of it. What was most surprising to me was the depth of their knowledge of U.S. developments and U.S. companies. Machine tool specialist Gavrilov wanted to know if control design had worked out in production; instrument designer Festa asked about Leeds & Northrup, Foxboro and Minneapolis-Honeywell; steel mill control specialist Charikov inquired about automatic pinhole detectors being used by U.S. Steel. And I don't think I've ever met engineers who were so intense about their work.

This intenseness was interesting for a different reason, too. Russian engineers apparently specialize quite narrowly; specialization occurs not only in technical fields but also geographically. For example, a question to Festa on computers drew only a blank look from the instrument designer. Computer specialist Ushakov apologized because he knew nothing about the KIEV computer (CtE, March '58, p. 26), explained it was being studied in the Ukraine and he (Ushakov) was from Russia. Although Elshin could not be stumped by questions in his field of process control in chemical applications, he apparently knew little about what was being done in metallurgical processing. In fact, he couldn't explain the operation of a Soviet ultraviolet analyzer, developed by a metallurgical instrument organization for metallurgical use, even though it turned out to be quite similar to infrared equipment designed by his own group.

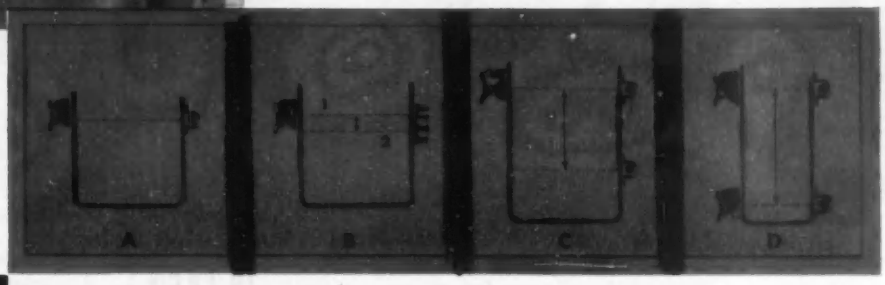
—Lewis H. Young

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High or Low Level Control . . . The detector is mounted diametrically opposite the radiation source. When the material moves above the level of the detector, the radiation is cut off, causing the output relay to change position. When the material drops below the level, the output relay is thrown to its opposite position. **Narrow Band Control** . . . The detector is mounted vertically along the tank, resulting in narrow band control. When the material moves above position (1), a signal is provided from the output relay. The opposite signal is provided when the material drops below level (2). **Wide Band Control** . . . A single source unit is teamed with two detector elements. The material can be controlled within the distance separating the high and low level detectors. The signal can also be used to provide a combination high-low level alarm system. **Extra-Wide Band Control** . . . Two source units are teamed with two detectors in cases where the vertical separation desired is large relative to the tank diameter. This system can also provide a high or low level alarm.

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Frequency to 1 kc/s

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Frequency to 400 c/s

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WHAT'S NEW

Underwater Techniques Reported at NTC

The program for the 1958 National Telemetering Conference, held in Baltimore in June, was probably the widest in scope since the conference started in 1950. And a number of papers impinged on the fringe of the field of telemetry. To this observer, two of the "off-beat" papers proved to be as interesting, and as significant, as any presented.

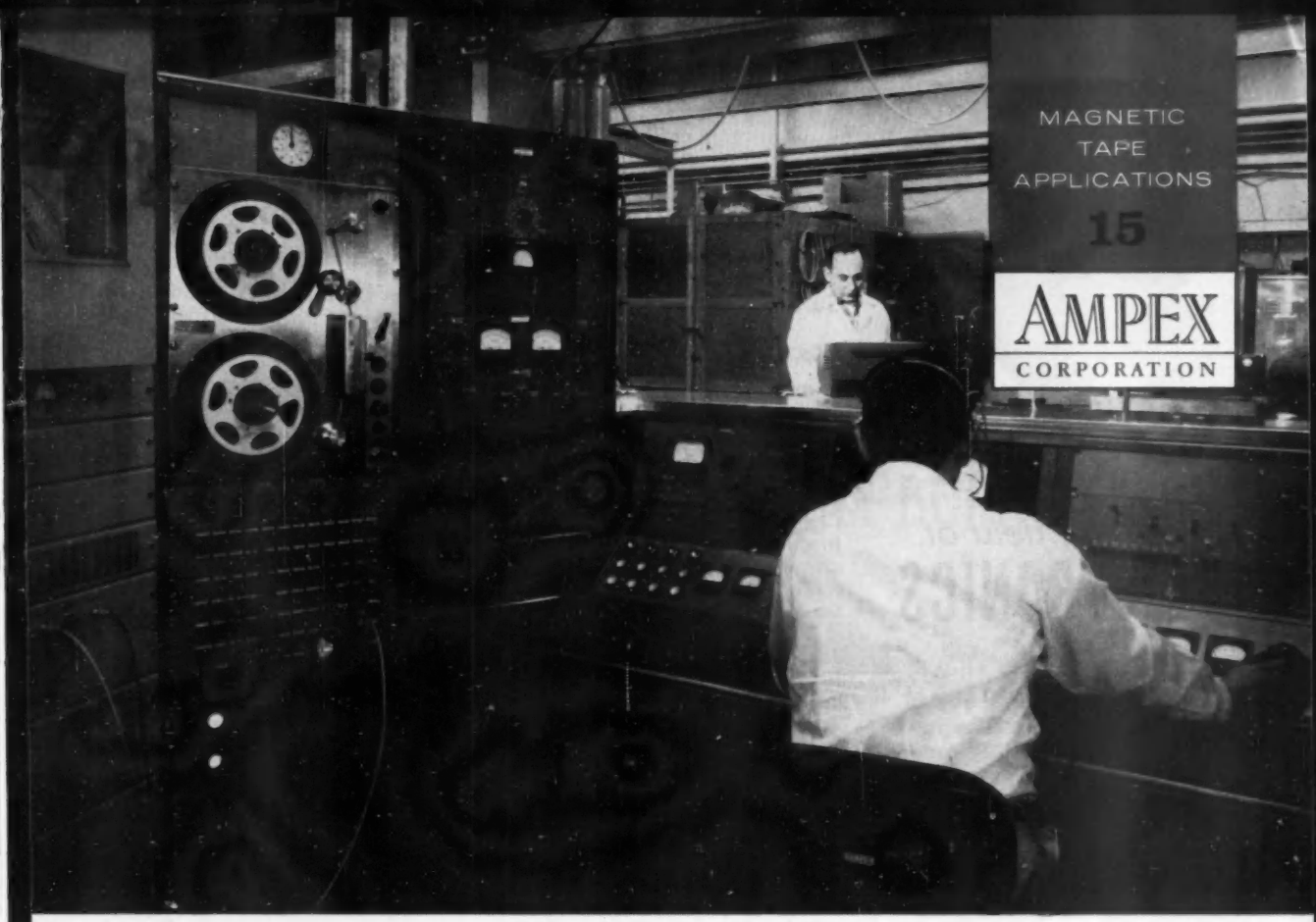
Ordinarily, bathymetry telemetry is not likely to arouse much interest in an engineering group; it's much too specialized. But the Navy's rapidly moving program for the Polaris missile, which is to be launched underwater, has cast a new light on underwater telemetry techniques. That's why James M. Snodgrass of the Scripps Institute of Oceanography drew such an attentive audience. Snodgrass discussed some of the techniques for measuring variables in ocean water; he also pointed out some serious obstacles.

For example, Snodgrass observed that water is practically opaque to electromagnetic radiations—the kind usually associated with telemetry. Oceanographers use wire telemetry or rely on acoustic waves instead. Among the underwater instruments described by the Scripps scientists: temperature transducers that measure pressure; a glass bulb that is imploded to measure depth—its acoustic wave can be picked up as far as 15 miles away.

In another session, the conference heard a description of a new kind of digital plotter, EDVAP (Electronic Digital Vernier Analog Plotter). James D. Perdue of the White Sands Proving Ground described how the system would work and the hardware that made it possible. He said the new plot was aimed at satisfying the needs of two major groups interested in missile tests: those who needed data in an analog form and the group that wanted data in digital form. EDVAP supplies both by printing performance curves with a series of dots that can be read digitally. Perdue expected the first EDVAP to be in operation by the middle of July.

Other papers covered such widely diversified areas as medical telemetry, IGY activities, mobile systems, and industrial telemetry.

Attendance at the Baltimore meeting was slightly disappointing—about 500, down 250 from last year's El Paso conference. —LHY



How to improve component reliability by better shake tests

Magnetic tape simplifies complex-wave testing and lessens human error



Many of the components that got their first ride on this tape-driven shaker are now circling the sky in Explorer I, our first successful earth satellite. It is highly significant that the California Institute of Technology Jet Propulsion Laboratory which led the development work on this satellite also pioneered complex-wave vibration testing. In this technique, magnetic recording plays many vital roles.

THE WAY TO OUTGUESS THE UNKNOWNS

Is simple sine-wave vibration testing sufficient? Or is a closer simulation of the missile's actual vibration environment a necessity? Results are not the same. Sinusoidal simplification often demands knowledge more complex than the complexities of a realistic test itself. Rocket components can bear neither the weight of excess safety factors nor the risks of conjecture – reasons why JPL chose random noise and complex waves.

Telemetered vibration tapes from actual missile flights are often used on shakers to assist development of test procedures. But this is not a complete answer. Different flights yield different vibration environments. A more ideal test-programming tape is a synthesized composite or envelope of the more severe conditions from many flights. This tape often combines random noise of engine vibration and complex waves from aerodynamic properties and structural resonances. And just as the missile's mass, velocity and surrounding atmosphere will change rapidly with time – so the taped program must change too.

Once on magnetic tape, any test program stays intact. It is repeatable without tedious setup and time-varying control of separate signal sources. With a properly calibrated tape, there is little chance that an operator will accidentally create destructive forces by errors in frequency or gain settings. Tape eliminates many possible sources of human error. It also leaves personnel free to concentrate on other requirements of shaker operation and test observation.

TAPE PASSES ALONG THE "IDEAL" TEST

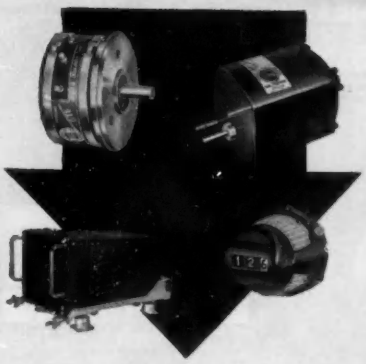
So that co-contractors and subcontractors will run desired shake tests correctly on the components they furnish, Caltech's JPL frequently sends them program tapes. These contain calibration data in addition to the program itself. Thus a similar shake-table setup on the other side of the country can exactly duplicate the tests run in JPL's own laboratory. The tape lessens chance of misinterpretations and additive safety factors.

As quantity production of missile components gets under way, magnetic tape offers a means to run optimum shake tests on large numbers of components at widely separated manufacturers. From copy tapes, test programs of complex waves can be run almost as easily as a simple sinusoidal scan. Individual users need not have equipment to generate their own shaker-control programs. Prime contractor or research co-contractor can furnish the tapes. And since any number of duplicates can be made, a well-conceived test program can have unlimited circulation.

May we send you our 16-page brochure on magnetic-tape instrumentation plus further information on the use of tape for vibration testing? Write Dept. HH-15.

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AROUND THE BUSINESS LOOP

Sun Shines on Control

Recession clouds part over many segments of the industry, giving the lie to some ominous predictions.

Even as Congress's Joint Economic Committee was preparing its early June report on the state of the nation, several things were taking place in the control field that promised to offset the congressmen's bleak predictions of a further slide in spending and a delay of business pickup until mid-1959 or perhaps even late 1960. Of the phenomena that had been shaping up, a number were in full view by the time the report appeared. Their implication was clear: despite the dark words from the Capitol, the recession, which had hit control and other hard-goods industries particularly hard, was on its way out. Here are some of the things that happened:

• Orders in May for computers built by Burroughs Corp.'s ElectroData Div. topped $8.5 million, a record; then in June they swept to a one-week peak of $2.3 million.

• More new service and engineering companies in the control field opened their doors in recent weeks than at any time in many months. A separate story on these new companies appears below (page 44).

• Employment at Kellogg Switchboard & Supply Div. of IT&T reached the highest point in its 61 years, exceeded the 1957 payroll alone by more than 6 percent.

• Bookings of material handling equipment manufacturers continued upward. Startling proof from The Material Handling Institute, Inc.: an increase in April bookings of 24.47 points over the bookings for March.

• New orders for machinery, a barometer closely watched by the McGraw-Hill Dept. of Economics, took another positive swing (its third in as many months).

• And, observed the McGraw-Hill economists, the ratio of inventories to sales and inventories to new orders, which had been climbing sharply, was now stabilized. Inventories were still declining, but this decline no longer lagged behind the decline in new orders and sales.

• A business analysis report from Lionel D. Edie & Co., Inc., New York investment counsellors, confirmed the McGraw-Hill outlook, said that new orders for durable goods rose in March, rose even higher in April.

• And, reported Edie, the Administration is meeting its objective on orders for hard goods. The objective: a $20 billion annual rate. Defense orders in the first three months of the year totaled $5.1 billion; in April they were about $1.7 billion.

In May, ElectroData sold 15 Burroughs 205 and 220 computer systems; in June, it sold six 205's to Redstone Arsenal alone. Also in June, it sold 60 magnetic tape transport units to a Paris computer manufacturer and signed a $17.5 million contract with the Air Force for 24 coordinate data processing systems to be used in SAGE. That contract, incidentally, brought the value of Burroughs computers ordered for SAGE to $90 million. (For a view of one installation in the vast SAGE network, see page 19.)

Overseas, Burroughs President Ray R. Eppert told stockholders at their annual meeting in Detroit, sales and service facilities have expanded 25 percent, manufacturing and marketing 9 percent. Sales outside the U. S. and Canada were 28 percent greater in the first quarter of this year than in the same period of 1957. Implied was the expectation that domestic sales would soon bounce back to provide some healthy competition.

• **Kellogg not alone**—Kellogg Switchboard is representative of the glossy picture at IT&T these days with respect to employment. In this division the payroll jumped from 2,337 to 2,491 within a year; throughout the IT&T system, it rose from 122,000 to 128,000.

Kellogg has already started moving equipment for the manufacture of carrier and microwave units into a new plant at Raleigh, N. C.

Dollar volume of orders in April, reported The Material Handling Institute, was 122.36, using 1954 as an index of 100; in March, they were 97.89. Many companies, said MHI President R. L. Fairbank, are improving and expanding their material handling systems with an eye on the competition. This indicates, he said, that buyers are dropping the wait and see attitude before authorizing increased expenditures for capital goods.

• **As Keezer sees it**—Here is the way

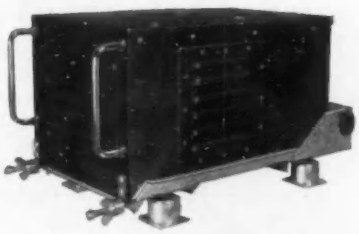
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Output frequencies; Stationary model — 1.0 mc, 100 kc; Mobile model — 100 kc.

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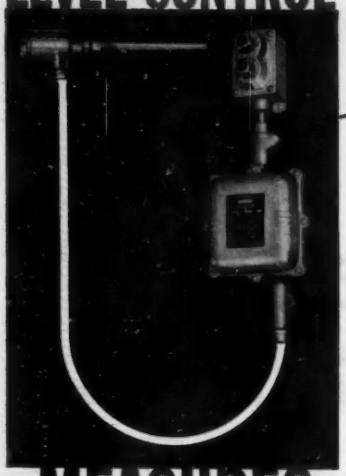
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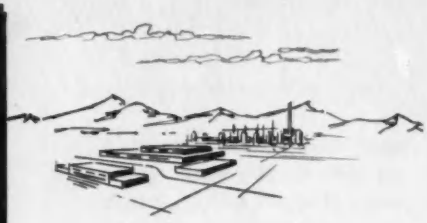
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THE GEORGE W. BORG CORPORATION

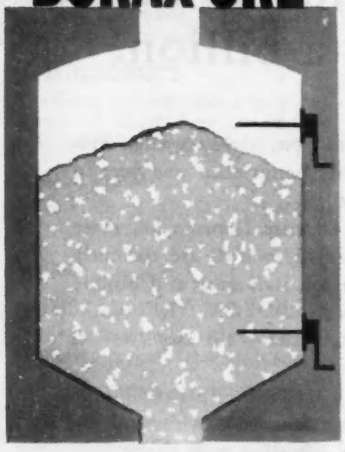
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Installed as high and low level controls in each of the huge receiving tanks, the R-F Tektors indicate automatically when the ore has reached a predetermined level. A built-in relay-actuated switch operates motor-driven valves and pumps to switch the feed from one tank to another.

Installed more than six months ago, U. S. Borax engineers report the instruments have been operating with extreme accuracy and have required no maintenance.

Thousands of Tektor Level Controls are now in use throughout the world, operating in various liquids, powders, granular and bulky materials and under almost all conditions of temperature, pressure or vacuum. The unit is available in four different types of enclosures including an approved explosion-proof type for hazardous locations. For further information write for Technical Bulletin F-101-4.

Other Tektor applications: Liquids, including water, acids, alkalies, oils and viscous liquids; powdered materials and bulky solids.

AERONAUTICAL AND INSTRUMENT DIVISION

Robertshaw-Fulton CONTROLS COMPANY

SANTA ANA FREEWAY AT EUCLID AVENUE • ANAHEIM, CALIFORNIA

WHAT'S NEW

Dexter M. Keezer, McGraw-Hill's chief economist, looks at the picture: "If orders pick up merely in the fields –like steel and textiles–where they have been almost nonexistent, this will have a salubrious effect on industrial production and employment. . . . Of course, the improvement in inventories and much of the increase in other demands, could be offset by a further disastrous slide in expenditures for new plant and equipment. But our indexes do not indicate that any such thing is about to happen.

"On the contrary, new orders for machinery are now turning up, after one of the sharpest slides in history–so sharp, in fact, that it apparently was overdone. The modest upturn so far does not mean another boom in capital spending. But it does reinforce the notion . . . that by the end of 1958 capital expenditures may be leveling out prior to an upturn sometime in 1959–not going into another, and worse, tailspin."

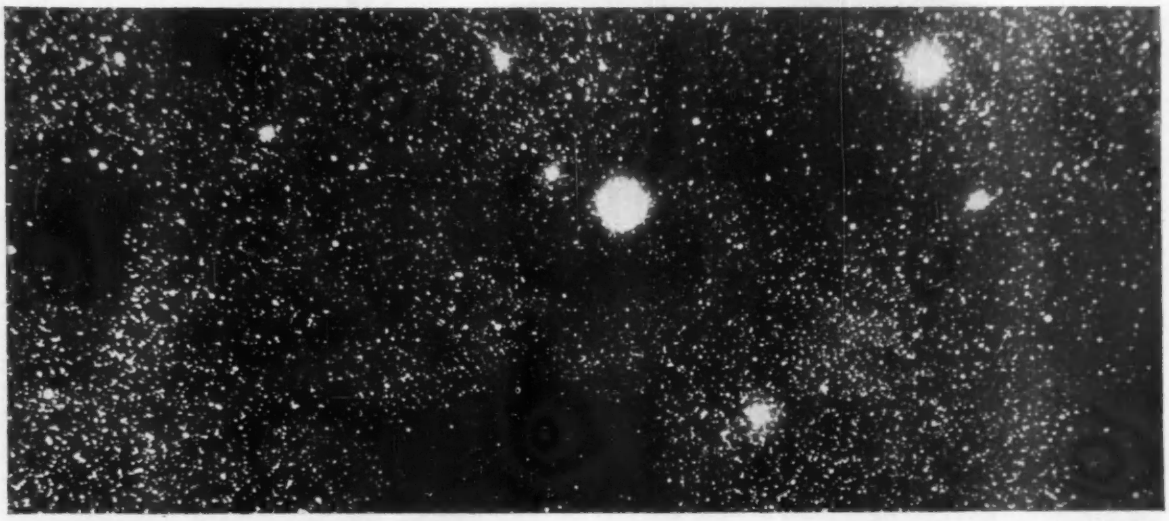
At the end of May, the Edie corporation said: "Industrial production in May is likely to be about the same or slightly higher than in April. This will be the first time that the production index has not decreased since last September. The June index of industrial production might show a rise . . . the April figure (for durable goods new orders) may be the same to higher than that of March. Defense new orders are a vital part of this newly favorable trend."

And that was the way things went, one note of encouragement following another, just after the dismal announcement on the state of the economy issued from Capitol Hill. If the members of the joint congressional committee had wanted to spread their gloom in an atmosphere of contrasting brightness, it is doubtful if they could have chosen a more appropriate time.

Epsco sells a Dataverter to the Army for $300,000

An Epsco Dataverter Computer Translater, the system that accepts inputs from just about any device and translates to the same kind of device or just about anything else, has been purchased by the Army Corps of Engineers. The $300,000 contract is apparently the first of its kind.

Dataverter is made of Epsco modular data control building blocks and will meet the requirements of any computer installation. Input media can be IBM punched cards, punched



Courtesy Mount Wilson Observatory

FROM BEYOND THE SKY TO BENEATH THE SEAS

In the field of communications, two extraordinary events have occurred within a short span of time. One was the linking of Europe to America by the submarine telephone cable. The other was the sending of radio signals from U. S. satellites in outer space.

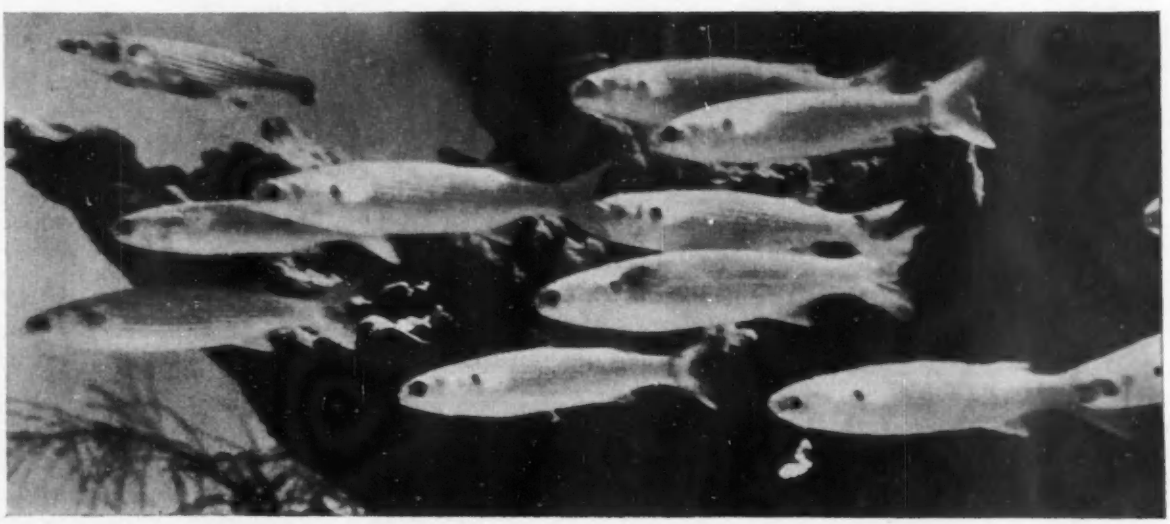
Both achievements depended on developments from Bell Telephone Laboratories. The cable was made possible by development of long-life electron tube amplifiers able to withstand crushing pressure on the ocean floor. The satellites derive their radio voices from transistors—products of basic research in semiconductor physics.

The deep sea amplifier and the transistor illustrate the wide range of work at Bell Telephone Laboratories. Here, over 3000 professional scientists and engineers explore and develop in physics, mathematics, electronics, chemistry, mechanical engineering, even biology—in every art and science which can help improve electrical communications.

Through this work, Bell Telephone Laboratories has helped make your telephone service the world's finest—and will keep it so.

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paper tape (in any tape code or code level), 1103A magnetic tapes, 704 magnetic tapes, or typewriter; output media can be any one of these, too. Dataverter will arbitrarily reorder information in blocks of 120 characters, delete unwanted data, and insert zeros or space codes where desired. A punched-card controlled tape-editing feature performs tape duplication.

Magnetic Amplifiers' Contract with Martin Brushes $1 Million

A new order for autopilots, for The Martin Co.'s new Mace missile, brings a Magnetic Amplifiers, Inc., contract with Martin to nearly $1 million. The contract covers the Matador, too.

Foxboro's Gross Sales Topped $16 Million in '57

The omission of a few key words in last month's story about a new Foxboro Co. stock offer (page 40) might have made an unfortunate insinuation. To clear things up, let the record show that last year this very lively company grossed $16,218,865 in sales and netted $3,947,209 in profits. The first figure reflected an increase of more than $4 million, the second an increase of more than $1 million.

More Companies Display "Open for Business" Sign

A healthy sign of the times, as was indicated in the story that opened *Around the Business Loop* this month, is the sudden appearance of a spate of new companies in the control field. One of the most interesting is Chance Vought Aircraft's **Genesys Corp.**, a wholly new subsidiary for advanced control computer systems and components. Commercial and industrial applications will be favored.

Genesys will operate in Los Angeles under H. B. Gibbons, president, and these v-p's: Geoffrey Post, engineering; John P. Lekas, product development; and John F. Davis, marketing.

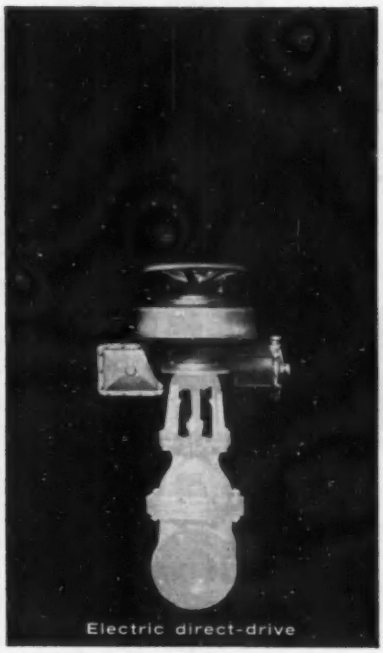
Other new companies are:

Space Technology Laboratories, originally an autonomous division of The Ramo-Wooldridge Corp. and now a separate corporation—in Los Angeles. STL has done systems engineering in the Titan, Atlas, and Thor ballistic-missile programs.

Delta-f, Inc., which will concen-



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For heavy duty proportioning applications, you'll find the HAMMEL-DAHL air-operated diaphragm valve worth looking into. *And no electrical control or power circuits are required in proportioning operation.*

No matter which you select for your particular job, the important thing to remember is: *General Controls is a single source for all three types... and in all standard sizes.* For full information, expert field help, write today to

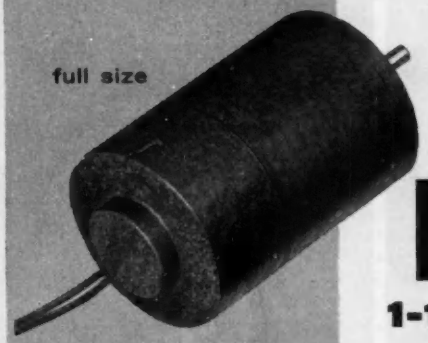
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With but slightly more than the diameter of a half dollar, this new space-saving, weightsaving d-c motor fits neatly into problem spaces. Explosion-proof cylindrical envelope. Designed to MIL-M-8609 specifications. Write for technical bulletins.

Let this compact, new Barber-Colman FYLM d-c motor help you answer design problems calling for limited motor area. Only 1.25" diameter . length 1.77" to 2.40". Capable of operating in ambient temperatures from −65°F. to +200°F, a typical continuous-duty 26-volt motor rated 15 millihorsepower at 9700 rpm, requires 0.6 ampere, and weighs 0.33 lb.

- **Patented symmetrical progressive lap winding.**
- **Double shielded ball bearings.**
- **Output shafts up to 3/16" may be specified.**
- **Dynamic braking can be utilized.**



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WHAT'S NEW

trate on frequency control systems, miniature packaged oscillators, transistorized frequency standards, and time-measuring instruments—in Batavia, Ill. President is John A. Cunningham, formerly manager of the Electronics Div. of Hamilton Watch Co.

Atlantis Engineering Corp., to specialize in automatic test equipment systems and equipment for the semiconductor industry—in Garland, Tex. Other interests of the new company include transistorized analog and digital amplifier units, automatic control systems, and consulting work. Most officers, including President and Chief Engineer R. L. Bickel, were formerly with the Test Equipment and Mechanization Depts. of Texas Instruments, Inc.

Manhattan Physical Research Group, Inc., an independent research service formed to help solve research needs of management—in New York City. Founder and President Cyrus Adler has taught physics and electronics at CCNY and the RCA institute; Vice-President Gerard G. Harris has been with the Berkeley Radiation Laboratory of the University of California, Brookhaven Laboratory, and Columbia University.

Inter-Mountain Instruments, Inc., formed to engineer and manufacture miniature variable reluctance and strain-gage transducers, and other products for industry and the military —in Albuquerque, N. M. President and chief electromechanical engineer is R. B. Bunker, formerly chief manufacturing engineer for Ultradyne, Inc., and before that with Sandia Corp., Statham Laboratories, and Aerojet-General Corp.

Robert P. Whorf, formed by the same to assist manufacturers of control equipment in "defining and evaluating" market needs for their new products—in Norwalk, Conn. In the past Whorf has dealt with new product and marketing problems in data processing, office equipment, control instruments and systems, and industrial and production machinery. His most recent position: director of research for Industrial Div. of Nowland & Co., Inc.

Associated Transistors, which will put into production the transistor developments of three British manufacturers that heretofore have been working independently of each other—in Ruislip, Middlesex, England. The three companies, which own Associated Transistors jointly, are English Electric, Automatic Telephone & Electric, and Ericsson Telephones.

IMPORTANT MOVES BY KEY PEOPLE

Jacobson, Bohrer Head IRC Engineering, Research

Leo J. Jacobson has been named head of the Engineering Div., and John Bohrer head of the Research Div., of International Resistance Co. Jacobson advances from chief engineer at Philadelphia and manager of quality control, posts he has held since joining IRC in 1949. Before that year he was with Western Electric Co. He is a committee chairman in Electronic Industries Association. Bohrer joined IRC in 1950 and most recently was assistant director of research.

Fogg Resumes CEC Helm; Colvin Appointed Senior V-P

Philip S. Fogg, chairman and chief executive of Consolidated Electrodynamics Corp., has resumed the CEC presidency, a job he relinquished in 1956. He will continue as chairman. The top-level administrative decentralization program responsible for the change also saw outgoing President Hugh F. Colvin named senior vice-president in charge of the Pasadena (Calif.) divisions, and two new vice-presidencies created. One of the new posts is held by Kenneth W. Patrick, who will oversee the Monrovia divisions, and the other by Frank M. Jenner, who will supervise Rochester, N. Y. operations. Patrick has been director of the Transducer Div., Jenner general manager of the Rochester Div.

C. L. Register Takes Over Burroughs Missile Div.

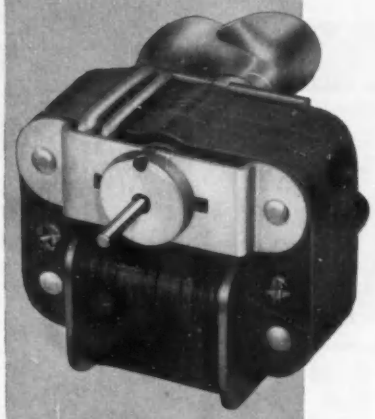
The Burroughs Ballistic Missile Div. at Paoli, Pa. has a big stake in the $60 million and more in Air Force missile contracts that already have been awarded to the Detroit company. Prime among the contracts assigned to the division is the one in Atlas guidance. The man who manages the Ballistic Missile Div. also heads up the Atlas program.

Recently Burroughs announced that C. L. Register, staff consultant to the manager of the Special Products Div. at the Burroughs Research Center in Paoli, had been named to this dual position. Register, the director of Army Ordnance Ballistic Research Laboratories, Aberdeen Proving Grounds, Md., before joining Burroughs last year, is a retired Army colonel and a former member of the

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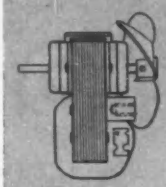


for timers, recorders, microfilm cameras, chart drives, switches, and similar applications

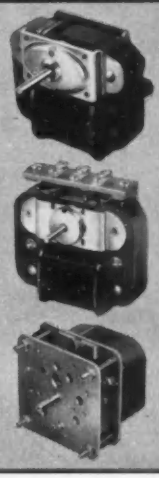
synchronous

.001 to .0045 hp

Barber-Colman synchronous small motors develop more than 30 times the power of ordinary clock and timing motors. High pull-out torque gives power reserve for operation under adverse load and supply voltage conditions. Synchronize rapidly to 3600 rpm synchronous speed. These are superior quality motors . . . with open and enclosed gear trains . . . to meet needs of a wide range of critical applications.



Cooling fans with accurately centered, polished aluminum blades are standard equipment for Barber-Colman synchronous motors.



other motors in the Barber-Colman line — unidirectional and reversible nonsynchronous motors — up to 1/20 hp — With and without reduction gearing — open or enclosed types. Expert engineering service available to help you get the exact motor needed, at the right price, for your application.

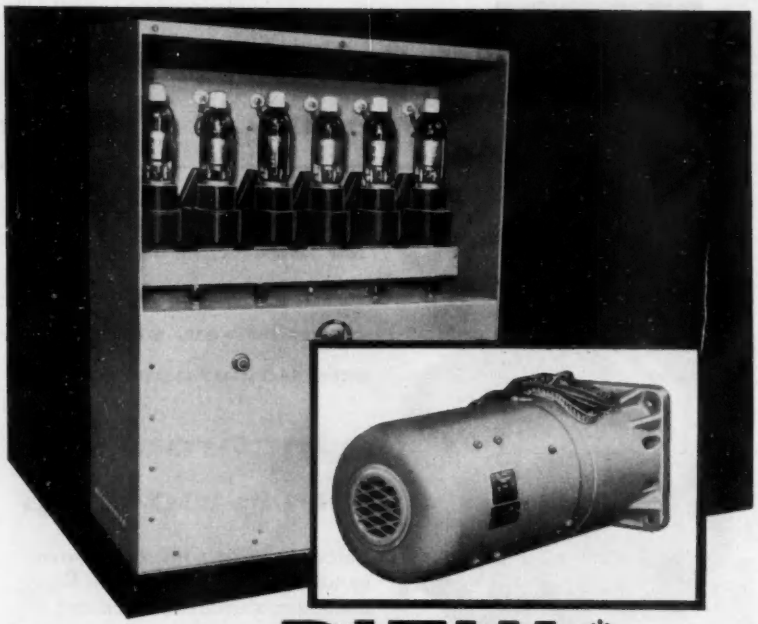
FREE CATALOG HELPS SELECT MOTOR NEEDED
Get this helpful condensed catalog of Barber-Colman shaded pole small motors. Contains complete descriptions of above motors, shows typical specifications, performance characteristics, control circuit diagrams. Write for your copy.



BARBER-COLMAN COMPANY

Dept. H, 1248 Rock Street, Rockford, Illinois

Small Motors • Automatic Controls • Industrial Instruments • Aircraft Controls
Electrical Components • Air Distribution Products • Overdoors and Operators
Molded Products • Metal Cutting Tools • Machine Tools • Textile Machinery



NEW DIEHL*

PACKAGE POWER AMPLIFIERS END POWER WASTE IN HIGH OUTPUT SERVOS

These new DIEHL small size, light weight Package Power Amplifiers achieve ideal motor conditions by providing constant 90° phase angle, infinitely smooth proportional reversing control and symmetrical control of motor voltage.

Important design and operating characteristics

- **Power gain per cycle**—can be unlimited.
- **Smooth 60-cycle AC (not pulsating DC)**—fed to motor by inverse-parallel connected thyratrons.
- **Low-impedance transistor-controlled grid circuits**—prevent accidental firing of thyratrons by external signals.
- **No special power source needed**—operates directly from 60-cycle, 3-phase power supply.
- **Tachometer feedback provided**—for AC or DC operation.
- **Exact 90° phase relation**—between control and reference phases.
- **85-90% efficiency.**
- **Response**—.008 seconds (½ cycle).
- **Driver stages**—Transistorized.
- **Rugged industrial thyratron output stage**—with 10,000 hour life expectancy.

ONE-SOURCE CONVENIENCE

DIEHL alone makes AC servomotors up to 3 HP range and now offers a complete package of Power Amplifier and matching AC Servomotors in these ratings.

Diehl*

SEE THE DIEHL DISPLAY:
BOOTH 428 AT THE WESCON SHOW,
LOS ANGELES, AUG. 19 to 22, 1958

DIEHL MANUFACTURING COMPANY

Electrical Division of THE SINGER MANUFACTURING COMPANY
Finderne Plant, SOMERVILLE, N. J.

Other available components:
A. C. SERVOMOTORS • A. C. SERVOMOTORS WITH A. C. TACHOMETERS
A. C. SERVOMOTORS WITH D. C. TACHOMETERS • A. C. AND D. C. TACHOMETERS
D. C. SERVO SETS • RESOLVERS

*A Trademark of DIEHL MANUFACTURING COMPANY

WHAT'S NEW

West Point faculty (Dept. of Mechanics).

He succeeds Edward Lohse, who has been named associate director of defense products, one of three new positions at the Research Center. The other two are director of commercial products, filled by U. C. S. Dilks, formerly manager of the Research Div., and manager of the new R&D Div., assigned to J. H. Howard, formerly manager of the Advanced Development Div.

Hickernell Succeeds Barrett as President of AIEE

The American Institute of Electrical Engineers (AIEE) has elected L. F. Hickernell, vice-president for engineering at Anaconda Wire & Cable Co., its 1958-59 president. The retiring AIEE treasurer succeeds W. J. Barrett.

Other Important Moves

Cyril M. McClellan takes charge of the entire engineering program at the California Technical Industries Div. of Textron, Inc., in his new position of vice-president of engineering. He comes from Westinghouse's Air Arm Div., where as manager of advanced development engineering, he was responsible for planning and directing long-range programs in airborne electronics. He had been with Westinghouse for 17 years.

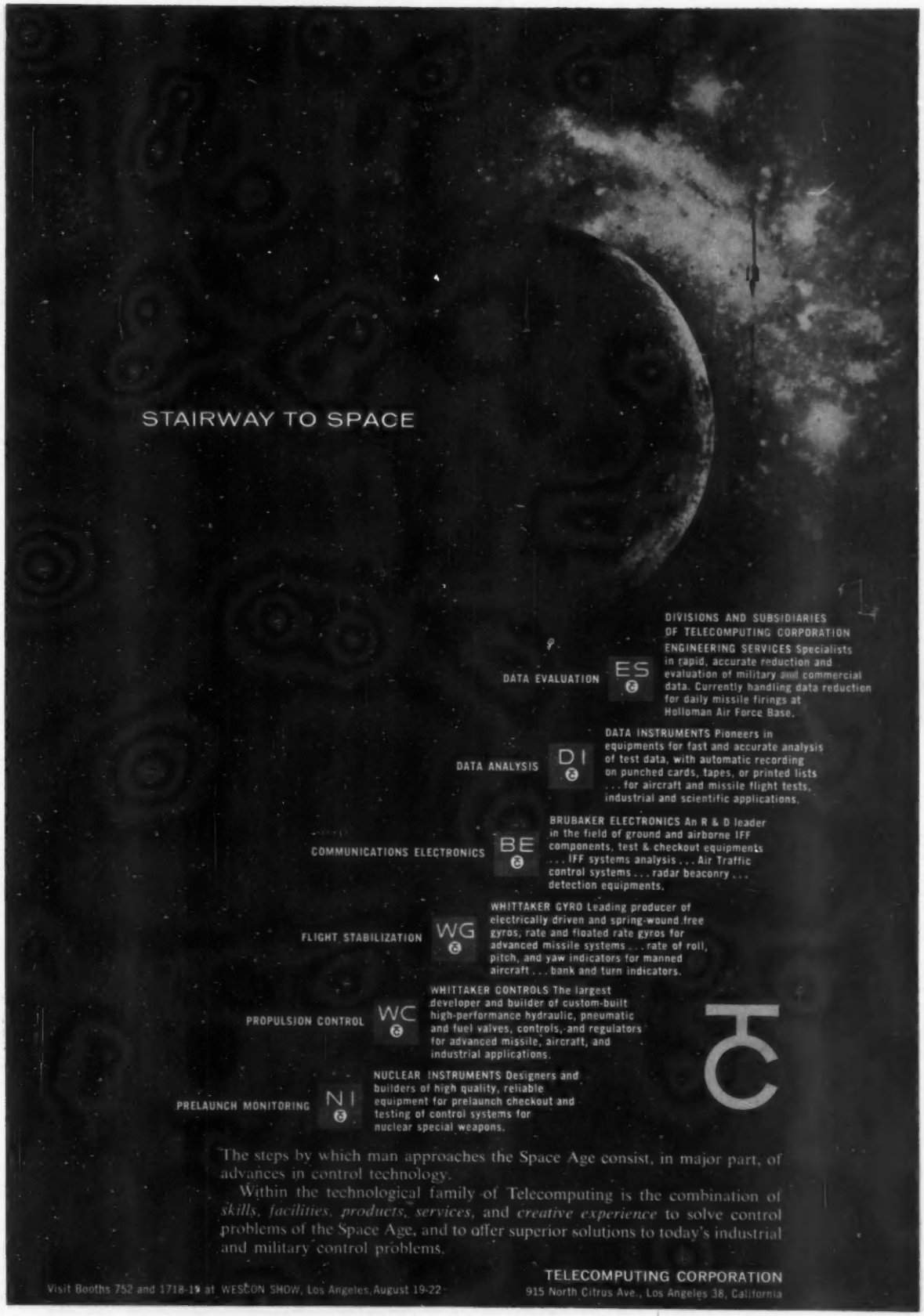
The new manager of special energy programs at Electro-Optical Systems, Inc., formerly was with Ramo-Wooldridge as head of the controls and auxiliary section in the Aeronautical Systems Dept. He is **James H. Fisher,** a 12-year veteran in the field. At R-W he did analysis and development work in ballistic-missile propulsion control.

Stromberg-Carlson has named **Clarence F. Van Epps** director of manufacturing in the Electronics Div., a section of the Telecommunications Div. Succeeding him as manager of materials engineering is **Ernest W. Goral,** formerly assistant manager.

Karl J. Klarman, formerly vice-president for engineering at Electro-Tec Corp., has joined the Instrumentation & Control Laboratory of Sanders Associates, Inc.

Obituary

William Hunt Eisenman, 73, secretary and a founder of American Society for Metals; at Palm Springs, Calif., following a heart attack.


STAIRWAY TO SPACE
DIVISIONS AND SUBSIDIARIES OF TELECOMPUTING CORPORATION
DATA EVALUATION
ES
ENGINEERING SERVICES Specialists in rapid, accurate reduction and evaluation of military and commercial data. Currently handling data reduction for daily missile firings at Holloman Air Force Base.
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DI
DATA INSTRUMENTS Pioneers in equipments for fast and accurate analysis of test data, with automatic recording on punched cards, tapes, or printed lists . . . for aircraft and missile flight tests, industrial and scientific applications.
COMMUNICATIONS ELECTRONICS
BE
BRUBAKER ELECTRONICS An R & D leader in the field of ground and airborne IFF components, test & checkout equipments . . . IFF systems analysis . . . Air Traffic control systems . . . radar beaconry . . . detection equipments.
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WHITTAKER GYRO Leading producer of electrically driven and spring-wound free gyros, rate and floated rate gyros for advanced missile systems . . . rate of roll, pitch, and yaw indicators for manned aircraft . . . bank and turn indicators.
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WHITTAKER CONTROLS The largest developer and builder of custom-built high-performance hydraulic, pneumatic and fuel valves, controls, and regulators for advanced missile, aircraft, and industrial applications.
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NI
NUCLEAR INSTRUMENTS Designers and builders of high quality, reliable equipment for prelaunch checkout and testing of control systems for nuclear special weapons.
The steps by which man approaches the Space Age consist, in major part, of advances in control technology.
Within the technological family of Telecomputing is the combination of *skills, facilities, products, services,* and *creative experience* to solve control problems of the Space Age, and to offer superior solutions to today's industrial and military control problems.
Visit Booths 752 and 1718-19 at WESCON SHOW, Los Angeles, August 19-22
TELECOMPUTING CORPORATION
915 North Citrus Ave., Los Angeles 38, California



Build Quality in Your Line with

BISHOP TUBING AND PLATINUM PRODUCTS

"Metals for Precision and Performance"

Quality begets quality — it's an established axiom that premium products must begin with quality components. BISHOP has been producing platinum and precious metal products since 1842 . . . *precision* stainless steel tubing since 1931. The BISHOP family of metal products includes a broad variety of components for the designer, engineer . . . just to mention a few:

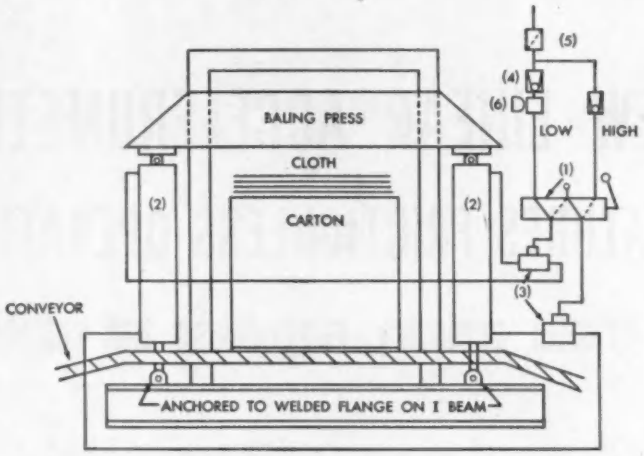
Capillary Tubing—standard and special sizes
Platinum & Platinum Alloy Wire—#50 to #3 B&S Gauge
Clad Metals—base and precious metals in various combinations
Glass-To-Metal Sealing Alloys—low expansion alloys
Thermocouples—noble metal and noble metal alloys
Tubing—nickel, stainless, platinum, special alloys
Tubular Fabricated Parts—all varieties
Composite Wires—base and precious metals in various combinations
Platinum Tubing, Contacts, Discs

CATALOGS, DATA SHEETS SENT PROMPTLY ON REQUEST

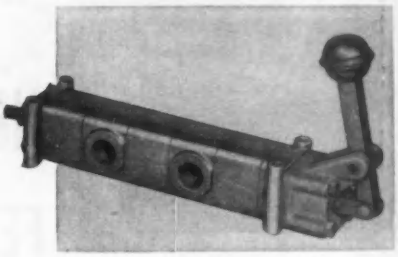
Begin your next design with *unexcelled* quality BISHOP component materials. Write, wire or phone Malvern 3100.

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platinum works
MALVERN, PENNSYLVANIA

Westinghouse air circuitry cuts packaging labor costs 28%



Devices: (1) PD4-42-0001 PILOTAIR® Valve (2) "A" Cylinder (3) Quick Release Valve (4) Reducing Valve (5) Filter (6) Lubricator



"D" PILOTAIR® VALVE

The Westinghouse PD4-42-0001 PILOTAIR® Valve is the key to this entire pneumatic control system. "D" PILOTAIR® Valves are two-, three-, or four-way directional valves, with lever, cam, solenoid, pneumatic, pedal, and treadle operation. They have two and three positions, with port sizes of ¼" and ½" ips. They provide a choice of over 30,000 valve operator positions. Maximum operating pressure: 250 psi.

The diagram shows a baling press at the Arista Mills Company in Winston-Salem, North Carolina, makers of blue chambray cloth. The press was recently converted from heavy gear operation to pneumatic control. The pneumatic control system was designed by the Livingston & Haven Company, of Charleston, South Carolina. Westinghouse Air Circuitry has enabled Arista Mills to put 28% more cloth in each carton. Since labor costs per package are about the same as with their previous method, they are realizing an approximate 28% saving in labor costs. The heavier, more fully packed cartons also have cut handling costs, cut carton costs, and made available more critical warehouse space.

What is air circuitry?

Air Circuitry is the Westinghouse term for application of pneumatic control systems to industrial production operations. Safe, economical, precise Air Circuitry is now being used to solve the most rigorous and complex control problems in industry. Westinghouse Air Brake has pioneered the application and development of air control for more than 80 years. Today our engineers can design an air circuit which will help you boost production and cut costs in your plant or shop.

See the Yellow Pages under Cylinders for the Name of Your Local Distributor



FREE BOOKLET

For more details, send for the free booklet, **Basic Pneumatic Control.** This informative 28-page brochure pictures and explains the advantages of Westinghouse Air Circuitry. We'll also send you a booklet of Datair Sheets containing diagrams and descriptions of recent Westinghouse Air Circuitry installations.

Westinghouse Air Brake Company
Industrial Products Division, Dept. CE-88
Wilmerding, Pennsylvania

NAME .....

TITLE .....

FIRM .....

ADDRESS .....

CITY ..... STATE .....

Westinghouse Air Brake
COMPANY
Industrial Products Division

WILMERDING PENNSYLVANIA



A-C Linear Accelerometer, Type LA-600, for aircraft and missiles. Shown actual size.

NEW LINEAR ACCELEROMETER

FEATURES FRICTIONLESS OPERATION

for greater accuracy, ruggedness and reliability

NEGLIGIBLE CROSS COUPLING

A-C VARIABLE RELUCTANCE PICK-OFF

MAGNETIC DAMPING

OPERATING TEMPERATURE -65°F to +250°F

NO WARM-UP TIME REQUIRED

HERMETICALLY SEALED

In the Honeywell A-C Linear Accelerometer, Type LA-600, friction introduced through bearings and potentiometer slide wires is eliminated. This unit consists of a non-pendulous seismic mass supported on a frictionless spring suspension and incorporates an a-c variable reluctance type pick-off.

Inherently insensitive to cross-coupling accelerations both when at null and when at an acceleration along its sensitive axis, the Type LA-600 also features magnetic damping for near-constant damping ratio throughout its wide range of operating temperatures. Mechanical stops prevent damage from input accelerations beyond the specified full scale range. Write for Bulletin LA-600, Minneapolis-Honeywell, Boston Division, Dept. 34, 40 Life Street, Boston 35, Mass.

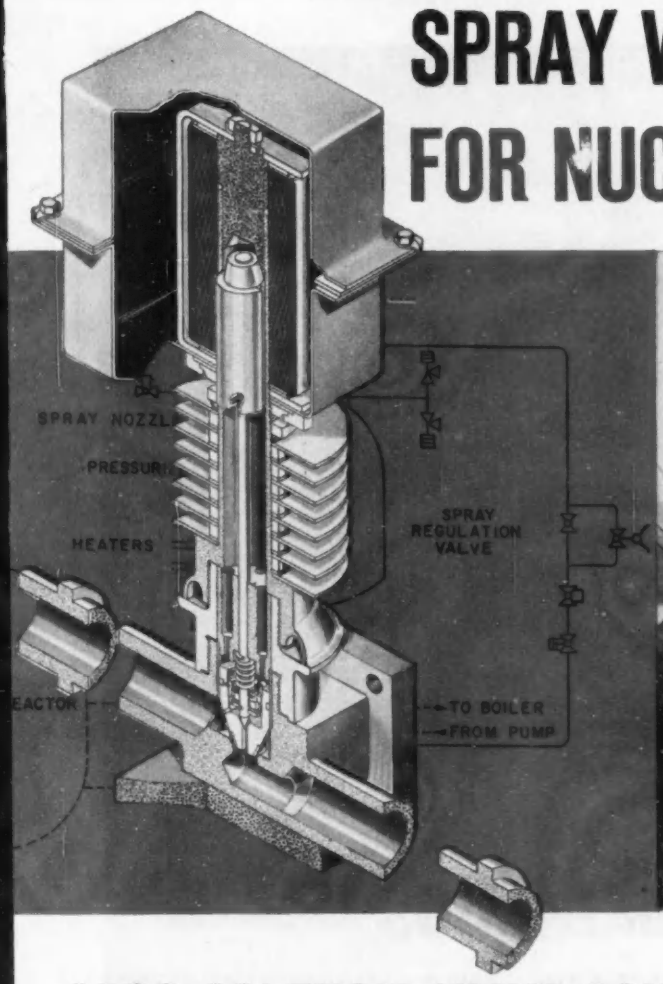
Honeywell

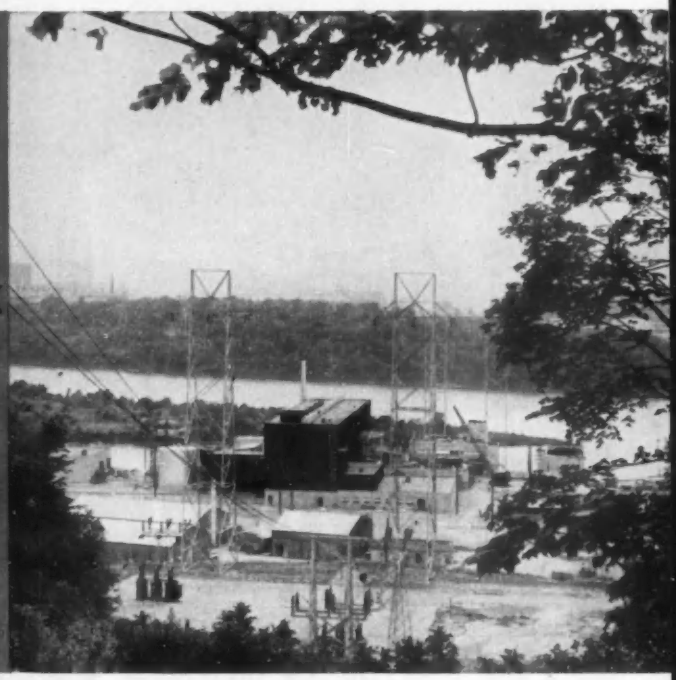
H Military Products Group

DESCRIPTIVE DATA

FULL SCALE RANGE:	±0.5 to ±40 G
FULL SCALE OUTPUT:	Up to 10v, 400 cps into 100 K load; Up to 8v, 400 cps into 10 K load
THRESHOLD-RESOLUTION:	.0001G
CROSS-AXIS SENSITIVITY:	.005G maximum
VIBRATION:	10G, 0-2000 cps
SHOCK:	Up to 60 G
WEIGHT:	1.2 pounds maximum

SPRAY VALVE FOR NUCLEAR REACTORS...





ASCO SOLENOID VALVE CONTROLS PRESSURE SURGES

ASCO – the only solenoid valve manufacturer in the industry with complete nuclear energy test facilities including a *hot test* loop – now offers a family of solenoid valves designed specifically for atomic energy applications.

The Spray-Valve shown in the cutaway above was developed especially to control pressure surges in the water cooled pressurized reactor. All stainless steel with stellite seats and discs, this unit has demonstrated reliability and maintenance-free operation under tests which duplicated the most strenuous operating conditions.

This packless type (hermetically sealed) solenoid valve is capable of large volume flow at low pressure differentials, handles pressures of 2500 p.s.i., at 675°F. Normally closed (closed when de-energized), it is supplied in 1", 1½" and 2" sizes.

ASCO Spray Valves are in use at Shippingport Atomic Power Station, and aboard nuclear submarines powered with water cooled reactors. Reliable and maintenance-free, ASCO 2, 3 and 4-way valves are specified for primary and secondary systems of nuclear reactors, as well as for instrumentation control.

For further information, request "ASCO Valves for Nuclear Reactors" and Catalog No. 202.

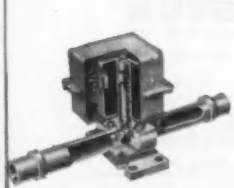
ASCO®

Automatic Switch Co.

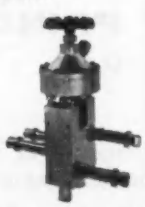
50-G Hanover Road, Florham Park, New Jersey
FRontier 7-4600

Typical ASCO Solenoid Valves for submarines, military and commercial surface ships, and industrial power plants:

Primary System



Isolating (Stop) Valve

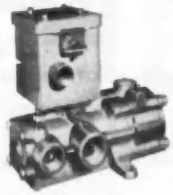


Pressure Operated 4-way Valve

Secondary System



Manual Reset 2-way Valves

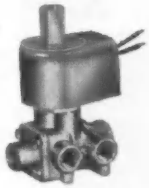


4-way Valves

Instrumentation Control



Manual Reset Valves



4-way Valves

FROM ASCOP



THE NEW MINIPLEXER®

TINY SAMPLING SWITCH — TREMENDOUS PERFORMANCE!

AN IMPORTANT ADDITION TO THE FAMILY OF

SMALLER • LIGHTER • BETTER

COMPONENTS

To the world of dramatically smaller components, ASCOP now adds the **MINIPLEXER®** — subminiature sampling switch that does a full-size job more reliably. The **MINIPLEXER** is the ideal companion to the transistor, the diode and the etched circuit for solving today's critical spacesaving, weightsaving and powersaving problems.

This tiny time-division multiplexing device contains 60 contacts, providing 30 channels of break-before-make operation. It weighs 2.37 ounces, is ¾ of an inch long and 1¼ inches in diameter. Yet, it will give longer service-free life and operate under more extreme environmental conditions than the much heavier, bigger switches it replaces.

The secret of the **MINIPLEXER** lies in exclusive ASCOP **DURAPOINT®** contact pins, developed through extensive metallurgical research. The pin material combines metallic hardness and low friction coefficient, permitting truly miniature design with low peripheral wiper speeds and longer life.

The **MINIPLEXER** is one of a family of miniaturized ASCOP **DURAPOINT** switches that will meet the ever widening range of stringent design requirements for your data and control systems. This family of miniatures also includes complete pulse telemetering commutator packages. For further information, contact any of the ASCOP offices listed below or write for Bulletin No. EM-100

ENGINEERING DATA —— ASCOP **MINIPLEXER**	
Service-Free Life	500 Hrs. at 30 RPS.
Ambient Temperatures	+125°C to −55°C
Vibration	Up to 2000 cps at 25 G

® APPLIED FOR

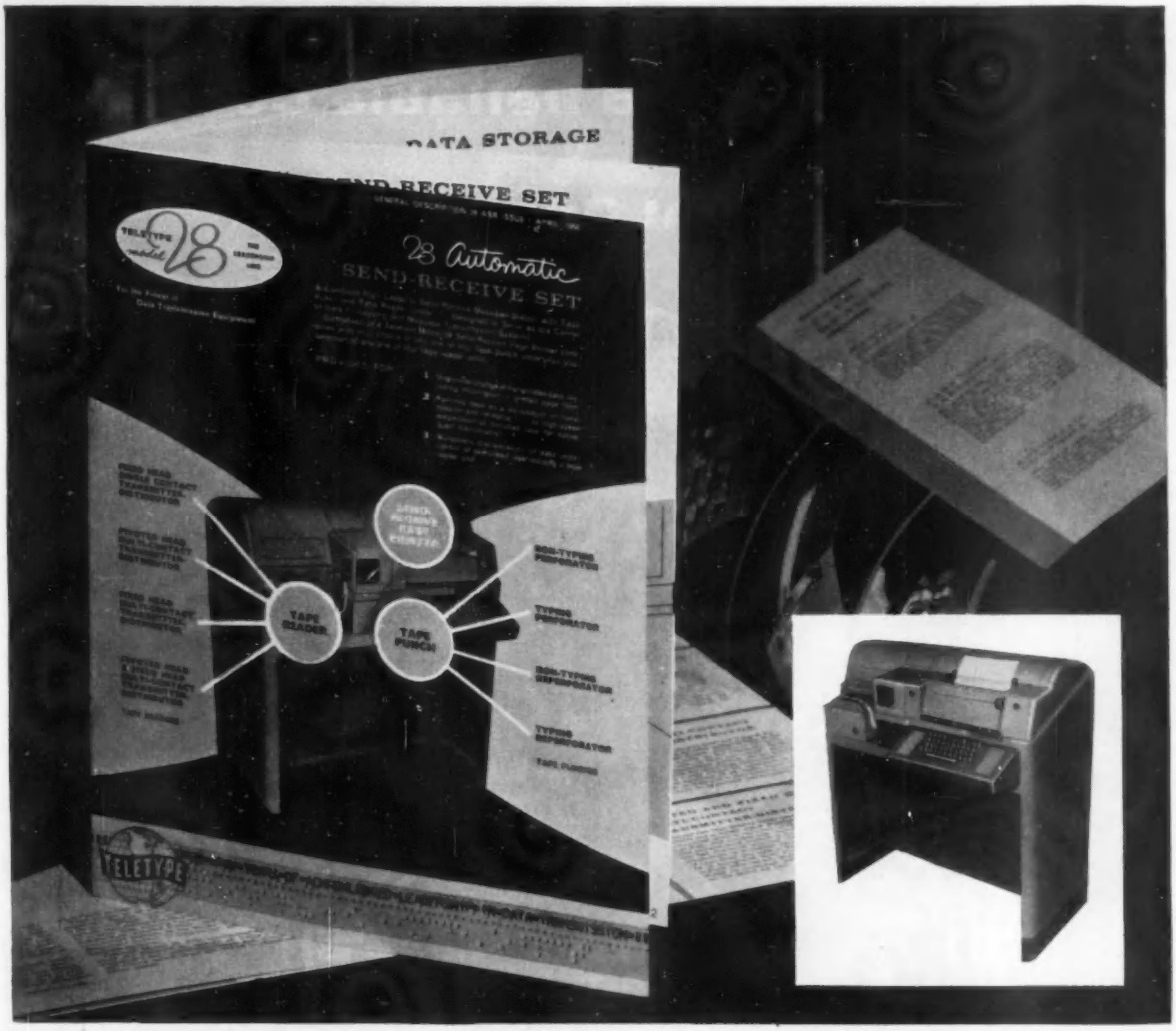
APPLIED SCIENCE CORPORATION OF PRINCETON

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FREE– Teletype booklet ...details new 28 ASR

Contents—Includes information on:

- Automatic communications
- New transmission speed
- Tape punching
- Tape reading
- By-product tapes
- Printing on tape
- Printing on forms
- Data processing
- Data transmission
- Data storage
- Aids to IDP
- "Robot brain"
- Reducing "clerical lag"
- Etc.

This 16-page booklet describes the new Teletype Model 28 Automatic Send-Receive Set.

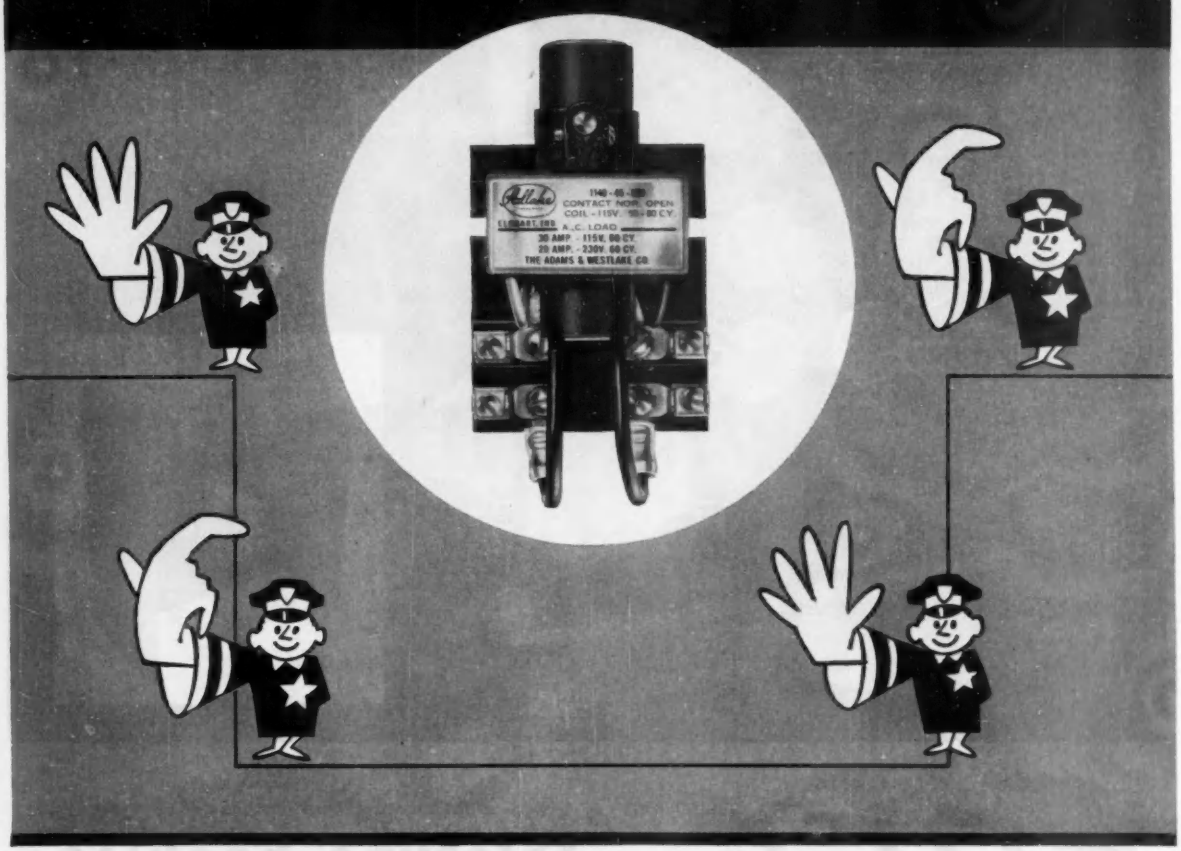
The Model 28 ASR is a "packaged" set—a single, compact console with a complete array of facilities—to serve as a center for your communication, data processing, paperwork simplification and automation systems. Operates at 100 WPM.

Please write for your free booklet on company letterhead.

Address: Teletype Corporation, Dept. 20 H, 4100 Fullerton Avenue, Chicago 39, Illinois.

TELETYPE®
CORPORATION
SUBSIDIARY OF *Western Electric Company* INC.

When You Need Reliable Control of Intermittent Operations...



you need Adlake mercury-to-mercury relays

Set up your requirements for the perfect relay to "police" a particular job—and beyond doubt you'll find yourself with this list of Adlake features:

- **Perfect snap-action—no burning, pitting or sticking**
- **No intrusion of dust, dirt or moisture—hermetically sealed at the factory**
- **Time delay characteristics fixed and non-adjustable**
- **Quiet. Chatterless. Require no maintenance whatever**

Our engineers will gladly help you with your control problems. No obligation. Just write the original and largest maker of plunger-type relays—The Adams & Westlake Company, 1181 N. Michigan, Elkhart, Indiana • New York • Chicago

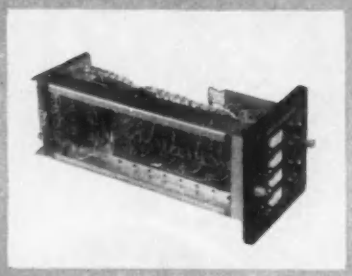
Adlake
THE ADAMS & WESTLAKE CO.

The Adams & Westlake Company
NEW YORK ELKHART, INDIANA CHICAGO
Established 1857

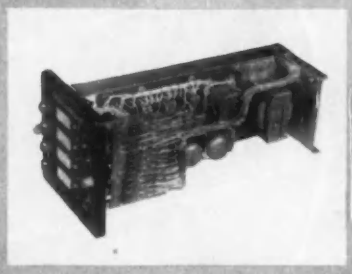
THOMAS A.

EDISON

New printed circuit model 310 omniguard temperature monitor



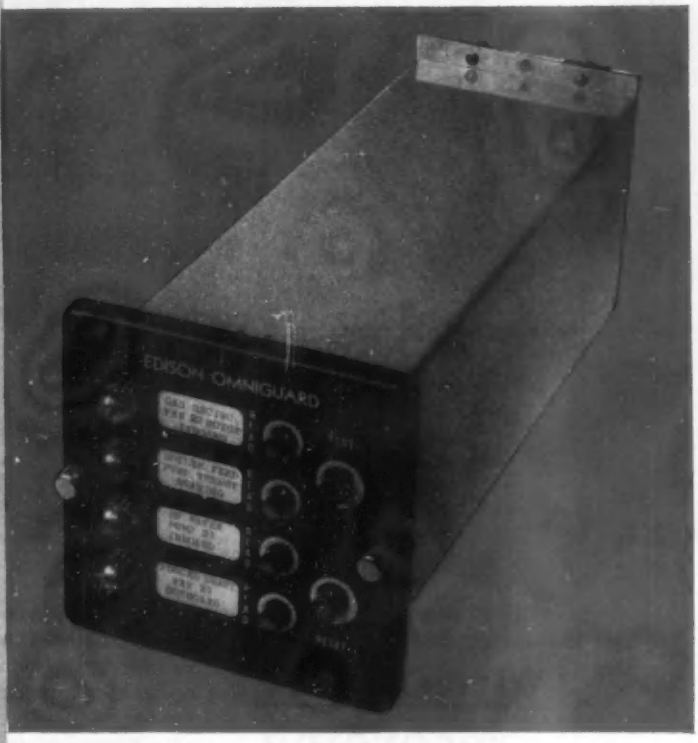
PRINTED CIRCUITRY INCREASES RELIABILITY AND FLEXIBILITY.



USE OF THE HIGHEST QUALITY COMPONENTS INCREASES RELIABILITY . . . ASSURING MAINTENANCE-FREE OPERATION.



DIAGRAM SHOWS TYPICAL OMNIGUARD SYSTEMS.



New Versatility . . . and *proven reliability* in temperature detection is made available with the introduction of the new Model 310. Printed circuit design and quality components guarantee a minimum of maintenance for the life of the unit.

Now, you have a temperature monitoring system incorporating all the flexibility, simplicity, quality and economy instrument and systems engineers have needed. The Edison Model 310 is a *mass produced* system whose modular construction makes it possible to have *custom-tailored* installation. Other important features of the new Omniguard Model 310:

- **Design keeps pace with growing instrumentation.**
- **Eliminates corrective maintenance and downtime.**
- **Complete Unit plugs in.**
- **Designed for more than a million operations.**

Call or write for more complete information.

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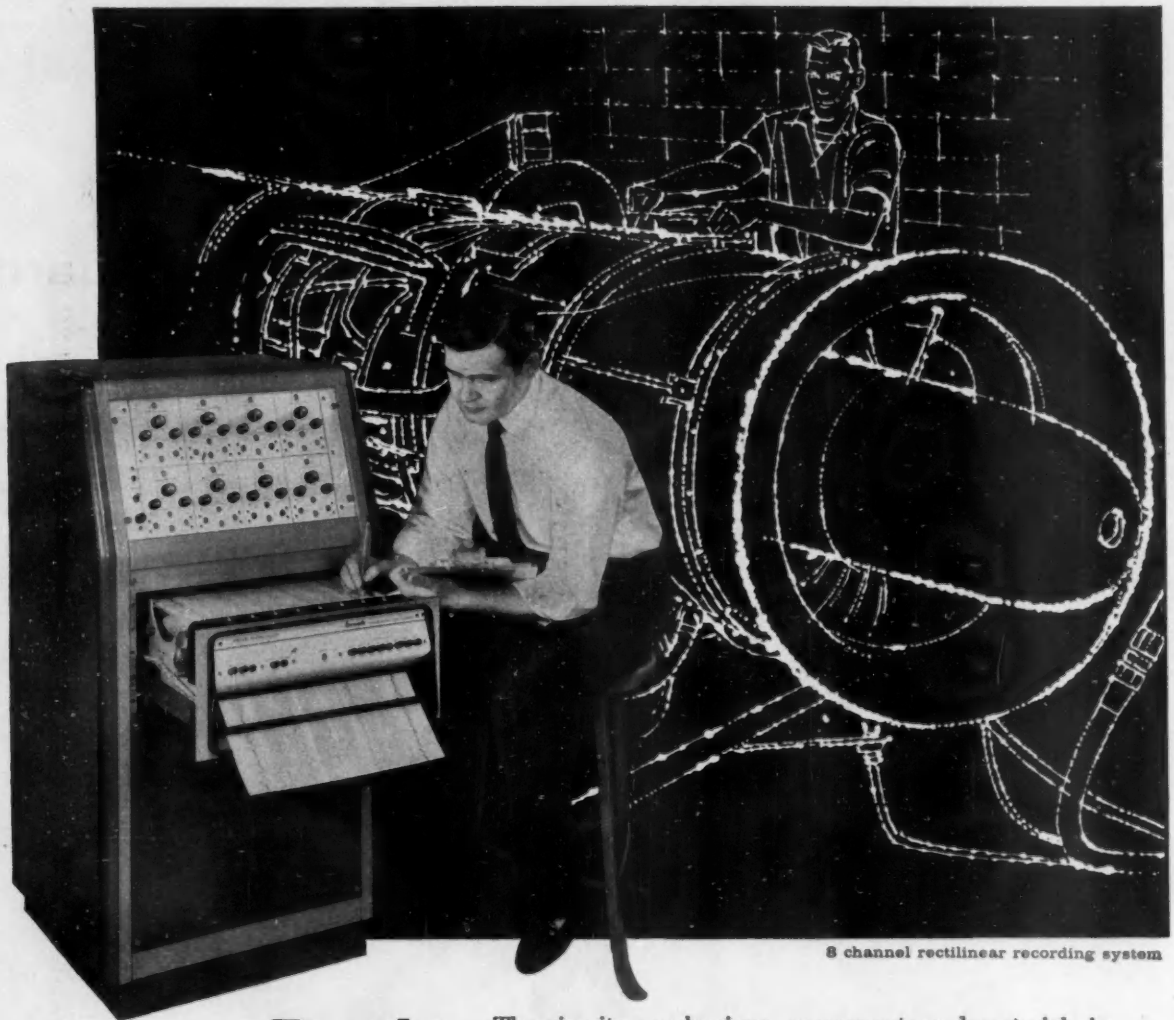
Thomas A. Edison Industries

INSTRUMENT DIVISION

38 LAKESIDE AVENUE, WEST ORANGE, N. J.

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8 channel rectilinear recording system

Brush ultralinear recording systems

...WHEN RELIABILITY IS OF VITAL CONCERN

The circuits, mechanisms, components and materials in this 8-channel recording system have *already proved their reliability* in Brush instrumentation now in use in the most critical applications—such as radar surveillance, computer readout, missile checkout on remote test ranges . . . in extremes of temperature, humidity and other abnormal conditions. At Brush, the high reliability factor is always a basic consideration in design.

In the system shown here, trace presentation is rectilinear. Thermal writing provides clear, sharp traces, excellent for reproduction. Eight chart speeds, stepped from .4 to 100 mm/sec., operate by pushbutton controls. The system readily adapts to pertinent MIL specs.

With their wide measurement ranges, Brush *Ultralinear* Recording Systems may be used for development and checkout of industrial as well as military equipment. Factory branches, service and warehousing at Arlington, Va., Boston, Cleveland and Los Angeles; engineering representatives in all key locations.

ASK FOR NEW CATALOG

Describes 2, 4, 6 and 8 channel systems—rack and mobile—ink, electric and thermal writing.

brush INSTRUMENTS

DIVISION OF CLEVITE CORPORATION

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Victor Regulators control high pressure gases...safely and accurately

GD700 SERIES for testing pneumatic components or operating gas systems. Gas-O-Dome primary regulator is controlled by a relief venting, high pressure, spring loaded regulator. This combination offers you precise regulation for both low or high volume applications.

MODEL	PSI MAX. INLET	PSI OUTLET RANGE	GAUGES (Integral or panel mounting)
GD710	7000	400-7000	10,000-10,000
GD711	7000	200-3600	10,000- 5,000
GD712	7000	200-2000	10,000- 4,000
GD713	7000	50- 800	10,000- 1,000
GD714	7000	10- 150	10,000- 200
GD700	3600	200-3600	5,000- 5,000
GD701	3600	200-2000	5,000- 4,000
GD702	3600	50- 800	5,000- 1,000
GD703	3600	10- 150	5,000- 200

Flow: Approx. 300 scfm. Leakage: None.
Operating temp. range: −67° F to +200° F (Storage −80° F)

LR SERIES Loading Regulators for "dead end" and low capacity testing (2 sfcm.) of pneumatic components, or for operating gas systems. Will hold dead-end pressures without leakage—also will hold supply pressure even when inlet pressure decreases.

MODEL	PSI MAX. INLET	PSI OUTLET RANGE
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LR19B	7000	20-3600
LR18B	7000	15-2000
LR17B	7000	10- 800
LR16B	7000	5- 200

Operating Temp. Range: −67° F to +200° F (Storage −80° F)
Leakage: None.

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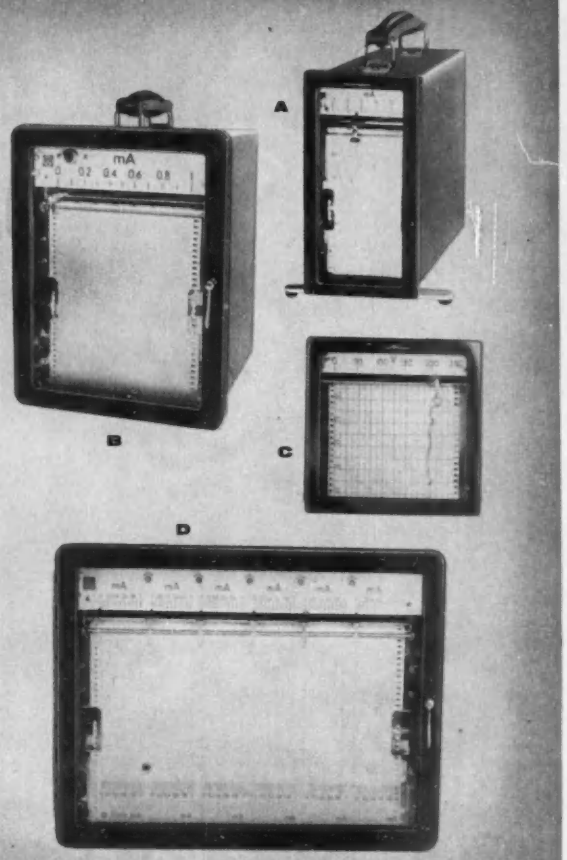
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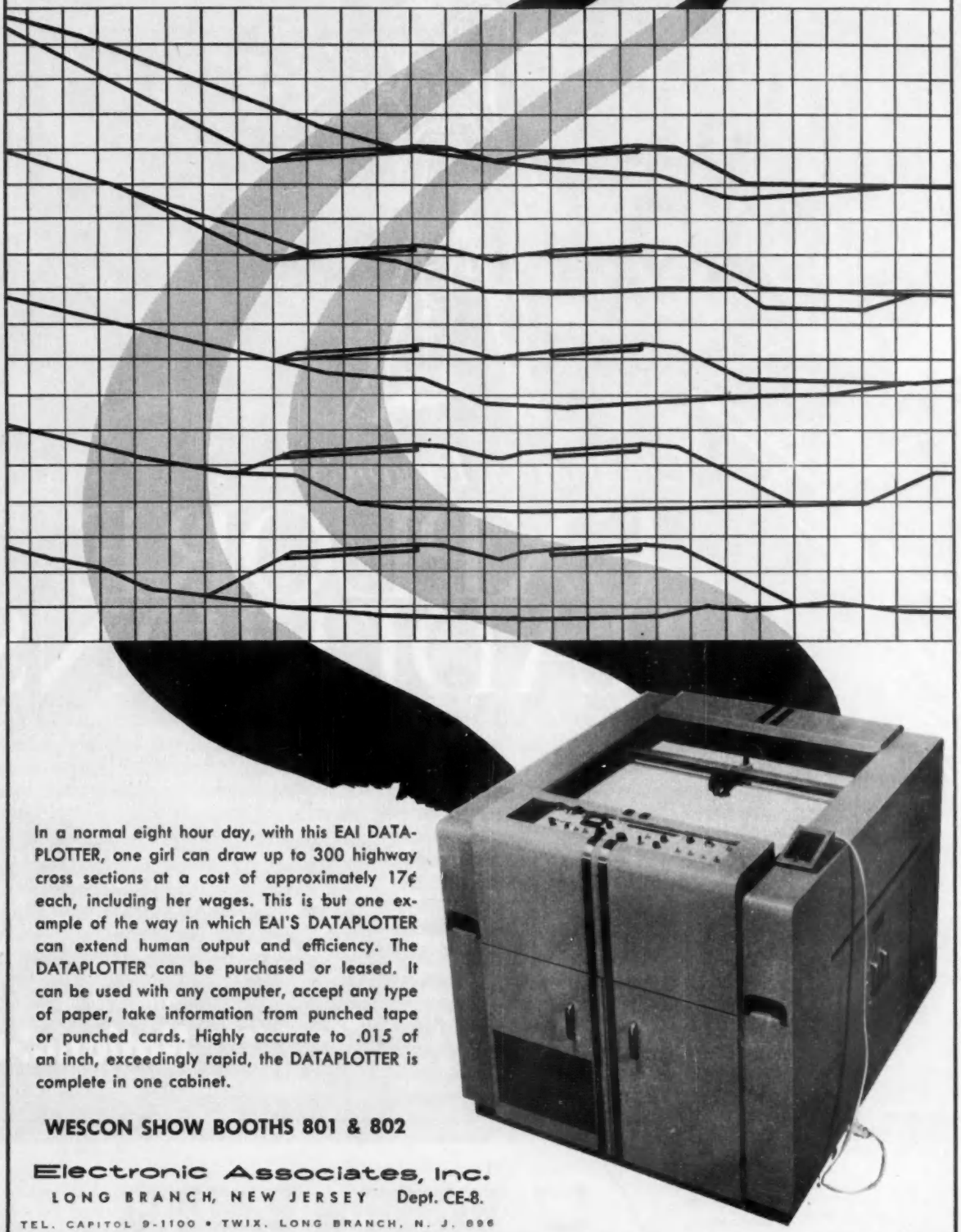
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Something New From West Germany

West Germany's control industry is growing at a phenomenal rate—averaging an annual increase of 30 percent during the past three years. About 150 companies have shared in this growth. And 10 of them are responsible for 60 percent of all control sales. The biggest: Siemens & Halske, AEG, Hartman & Braun, Brown Boveri & Cie, Schoppe & Faeser, and Eckardt.

Some of the biggest technological advances are being made in the process control field (see page 21 for details displayed at ACHEMA). In this area, German industry feels it has some new ideas. For example, in electric controllers, the Germans favor mixing transmitter signals at the input of the controller rather than using cascade systems.

Hartman & Braun's Universal Measuring Control system employs this technique. UMC uses separate proportional, integral, and derivative units. In the proportional unit, the sum or difference voltages are taken from up to five transducers. Tube amplifiers provide the 0.20-ma output.

West Germany's next step: nonlinear controllers. There are four companies already in the field. Siemens has put its Teleperm system in a rolling mill for field testing. H&B will install one soon, too.

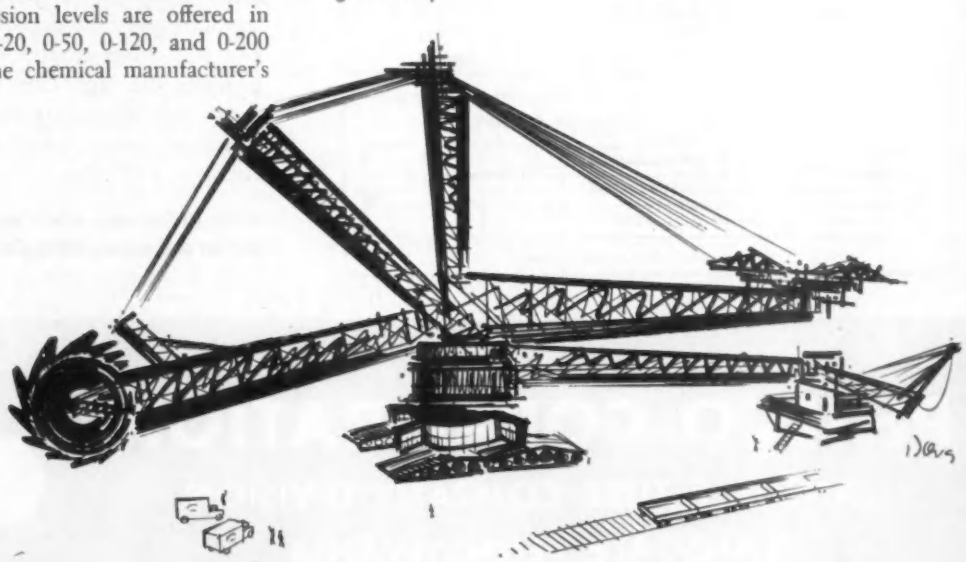
The keenly competitive situation developing between process control manufacturers has let users in for some problems. For example, in electric process control systems—most firms make a complete system from transducer to actuator—electric transmission levels are offered in a variety of ranges: 0-20, 0-50, 0-120, and 0-200 ma dc. NAMUR, the chemical manufacturer's control association, is urging standardization. NAMUR wants everybody to build 0-50-ma dc systems, but such standardization is years away.

Applications of program control to heavy machinery are scarce, but some unusual ones are starting to appear. A giant coal cutter for open-pit mining uses a system developed by Brown Boveri & Cie (see drawing below). Digital measuring techniques determine and control 1) the depth of cut by the rotating cutter, 2) the swiveling speed and angle of the head, and 3) the length of forward steps.

U. S. companies are having their influence, too. Some, like Beckman Instruments and Minneapolis-Honeywell, have established German manufacturing subsidiaries. Others have signed agreements to exchange know-how and patents. Westinghouse, for example, has a pact with Siemens.

This accord has stimulated Siemens, which has already developed fully transistorized computers and data loggers, to develop control systems using solid-state sequence control units. The company plans a big marketing push, strengthened by Westinghouse experience with Cypak.

To back up this booming control industry, Germany is turning out almost 40,000 engineers a year, to whom control fundamentals are taught as a subsidiary subject. At two Technische Hochschule (Darmstadt and Aachen) control engineering is the main subject. Professors Oppelt and Schafer are training 50 fully qualified control engineers a year.



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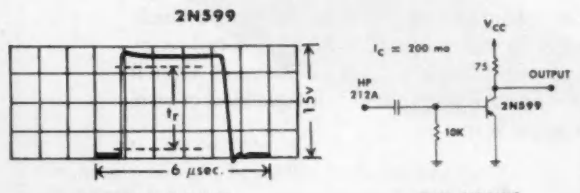
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- **High Current: Max. I_C = −400 ma**
- **High Temperature: 100°C Max.**
- **High Voltage: Max. V_{CB} = −30v**
- **High Frequencies: Min. $f_{\alpha b}$ to 12 mc**

PERFORMANCE DATA

Type	General Performance: Minimum f_{ab}	General Performance: Typical h_{FE}	Max. Ratings: I_C	Max. Ratings: V_{CB}	"ON" Switch Performance Max. V_{CE}	"ON" Switch Performance Max. V_{BE}
2N597	3 mc	V_{CE} = −1v, I_C = −100 ma 35	400	30	0.2	0.34
2N598	5 mc	V_{CE} = −1v, I_C = −100 ma 90	400	30	0.2	0.34
2N599	12 mc	V_{CE} = −1v, I_C = −100 ma 105	400	30	0.2	0.34

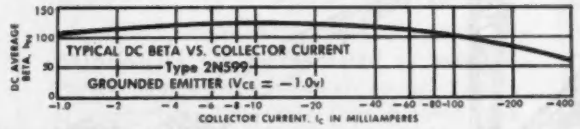
Total Device Dissipation at 25°C = 250 mw

TYPICAL RISE TIME CIRCUIT



SWITCHING TIMES — TEST CIRCUIT

TYPICAL DC BETA VS. COLLECTOR CURRENT



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TRANSISTOR CENTER U.S.A.

Control
ENGINEERING
AUGUST 1958

GRASS ROOTS: two-way benefits?

Last month a special ISA task force appointed by President-Elect H. C. Frost discussed a year-old proposal to regroup most of the ISA into five new regions. If approved, the regrouping should provide polite but firm competition for ISA locals and thus a convincing argument for integrating local technical conferences and accompanying exhibits. Urgent questions swarm from the local sections: will National develop the technical programs, sell the exhibit space, handle the promotion, and reap the financial profits? And why shouldn't an aggressive section conduct symposia and exhibits of specific interest to its locality, whether on flight test instrumentation, systems engineering practice, analysis instrumentation, machine tool control, or what have you? The general reply from National is that the innumerable local exhibits make time, travel, and dollar demands on viewers and exhibitors alike that are out of keeping with their size, influence, or customer-drawing ability, and thus cause headaches for the attendance-minded planners of the big annual ISA event.

In the IRE, where there is less competition for the national meeting's attendance and money, solidarity can and has been shaken by rivalry among sections to host a regional meeting. But here National arguments urging a respect for logic have brought sections to a more realistic attitude. IRE's success in nudging its sections toward community action, says Exhibits Manager William C. Copp, has been remarkable. He proudly cites the case of San Antonio and Houston, which have experienced equal benefits every time Dallas hosts a regional convention.

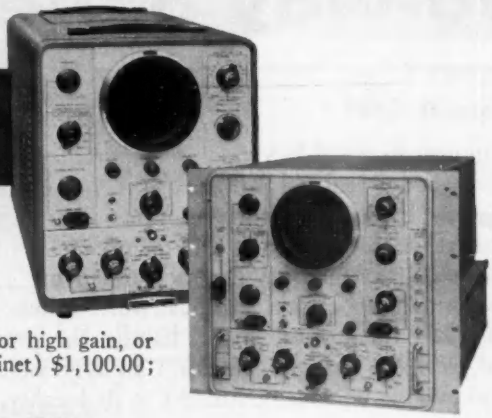
The question here, which concerns nothing less than the continuing health of the ISA, IRE, and all the other professional engineering societies that maintain formal grass-roots sections, is whether a national society will more successfully fuse communities of sections through decree—or through reason. Reason says that communities of sections, by pooling resources, can multiply the effectiveness of the basic technical society job —to provide a meeting ground for updating and for sharing technical experience. Reason also says that any incidental net profits, in kind or in coin, should return to the local sections.

W. E. Vannah

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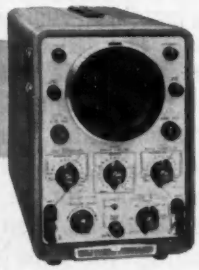
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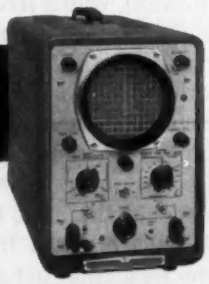
dc to 300 KC—$650

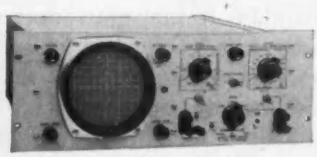




Models 130A/BR, similar horiz. and vert. amplifiers, input circuits balanced 5 most sens. ranges. Single ended input ac or dc coupled. 1 μsec/cm to 12.5 sec/cm; 21 sweep times. 130BR includes x 5 magnifier. 130A (cabinet) or 130BR (rack) $650.00.

dc to 200 KC—$435





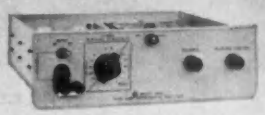
Models 120A/AR offer outstanding value, low price. Automatic trigger, 15 calibrated sweeps, sweep speed range 1 μsec/cm to 0.5 sec/cm, x 5 magnifier. Extra rugged, simple to use. 120A (cabinet) or 120AR (rack) $435.00.

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-*hp*- accessories extend oscilloscope performance



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-*hp*- AC-21C 50:1 Voltage Divider Probe for 150A but usable with most other 'scopes, VTVM's, preamplifiers. 10 megohms input impedance; 2.5 μμf input capacitance. $25.00.



-*hp*- 115A Oscilloscope Cart. Designed for 150A, fits other 'scopes. Heavy chromed tube steel construction, lightweight. Scope shelf tilts 30° in 7½° increments. 4" rubber tired wheels, brakes. $80.00.

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A Control Earning Index

PART I - How to Calculate It

The need to economically justify the equipment that he purchases is not new to the industrial control engineer: economic pressures have forced him to estimate original cost ("Instrumentation Costs of Process Plants", CtE, Feb., p. 88, gives typical figures). But seldom has he been able to predict the increment of improved plant economy that the equipment will effect by reducing consumption of raw materials, lowering processing costs, and increasing product uniformity. Part I of this article shows a four-step method for making this prediction. Part II, to be published in October, will report on experience in applying the method to:

- **a plastic film extruder**
- **a floor-tile calender**
- **a rug-back sizing machine**

W. E. VANNAH
Control Engineering

The industrial control engineer approaches process control with a knowledge of the energy balances and material inventories that must be maintained to produce specified products. He knows how the processing machinery, vessels, and heat exchangers work. Detailed information on the characteristics of measurement and control apparatus and know-how for applying them are readily at hand. So is the fund of theoretical and empirical data on the dynamic interrelationships of the process variations, the process equipment, and the control apparatus, and this fund is growing steadily. The control engineer thus can confidently engineer automatic systems that control the process so that it turns out product with the required properties.

But he will not know whether these systems will operate at minimum cost until he develops an economic understanding of the process that is as complete as his technical understanding. History is on his side. If he knew for certain that future control systems would have earning power equal to that reported in this statement by the chief instrument engineer of a chemical company, he would have no economic justification problem at all: "Our most significant improvements in purity, increases in throughput for existing equipment, and increases in product uniformity have been brought about by the addition of either analytical instruments or by rearranging the existing instruments into tighter control loops, or by the combination of both. When we have studied the economics after installation, it has not been unusual for us to find savings to the company of anywhere from $50,000 to $150,000 per year by adding instrumentation that cost from $10,000 to $15,000."

Since it is not reasonable to expect nine-to-one earnings from the majority of new or improved measurement and control installations (some may earn nothing but publicity), it is necessary to calculate what proposed installations can earn. To do this realistically, the control engineer needs to know the costs of available measurement and control apparatus, the complete economic environment of his process, and a few statistical techniques. The first item is covered in other CtE articles (Refs. 1, 2, 4). A box on page 69 discusses general process economics. The following steps cover detailed economics and the statistical techniques.

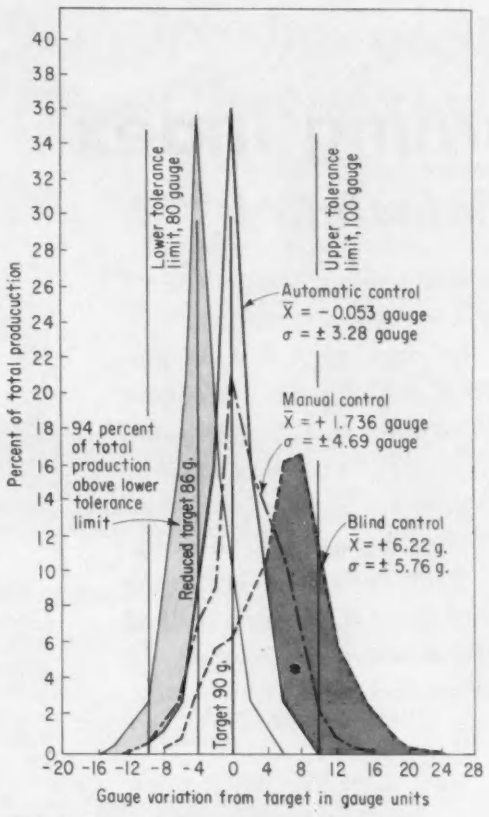


FIG. 2. Graph of plastic film quality distribution shows that operators of processes not equipped with adequate instrumentation run the quality higher than necessary, and that fully automatic control decreases the percent of off-target production.

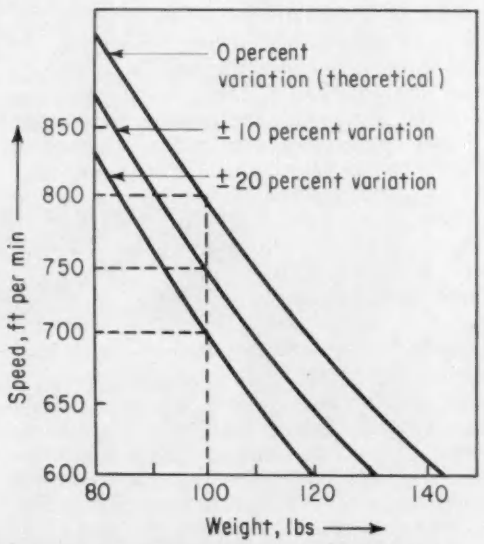


FIG. 3. Plot of paper-machine sheet weight reveals that machine speed, and therefore production, can be increased when high deviations from target are reduced.

STEP 1.
Look for potential improvements in . . .

. . . material savings
. . . improved product uniformity
. . . processing time savings

An operator without a continuous display of product quality measurement in front of him must depend on discontinuous measurements (mechanical measuring devices or production control laboratory measurements). These reduce the number and extent of deviations that he can correct and thus allow a wider spread of product quality about its target value. Operators of mechanical processes such as calendering or rolling, who are not adequately equipped with instrumentation and automatic controls, consistently run product gauge on the heavy side because they are on tonnage incentive or because they are trying to avoid producing dangerously light product. The light gray graph in Figure 2 demonstrates the wide spread and the tendency to run heavy. Product shown heavier than target may be acceptable by the customer, but it represents an unnecessary consumption of raw material and processing energy—and thus an opportunity for saving. The same can be said about the spread below the lower tolerance limit, which represents product that will, if ever detected, be rejected. The light gray graph shows how application of automatic control to the same process narrows the distribution of weights, increases the percentage of on-target production, and decreases the median of the entire weight distribution, all of which save material and improve product uniformity.

Material savings depend on units of output or sale, but process time savings do not. Time savings mean lower output cost per unit, whether the sale is made by area, weight, or individual unit. These savings result from faster process speeds, less recycled product, and faster startup and order changes. Human perception and action speeds are only two limits on machine speed. In paper-making, coating, and fabric impregnation, drying and curing capacities also limit machine speed. With limited drying capacity, heavier materials require slower speeds because more mass must be dried per running foot of material. And when weight variations in the material are uncorrected, the machine speed must be held down to dry the heaviest section of material-in-process. A reduction in the range of weight variations like that shown in Figure 2, when control was upgraded from manual to automatic, may permit an increase in machine speed. Figure 3 is a plot of paper-machine speed vs. product weight for three degrees of weight variation. The plot will be like this, whether for variations in the machine direction or the cross-sheet direction. It shows that reduction of weight variations about the target weight raises the maximum speed at which the machine may run and still dry the paper properly. Faster startups,

Process Economics . . .

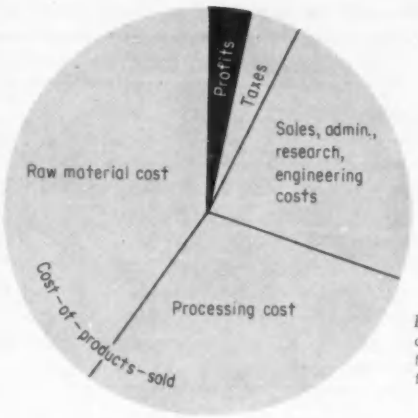


FIG. 1. When cost-of-products-sold mounts, the profit slice of the economic pie shrinks.

. . . starts from the viewpoint that the process is a money machine, a device that adds value to raw materials, yet also expends money, to form a marketable product. The important cost items are raw materials and operation. In the sheet-product and tube-product manufacturing industries (steel, plastics, paper, tobacco, and rubber), the processing operations have a lot in common. In all of them a partially processed material is passed over and through rolls while it is squeezed, dried, impregnated, wrapped, or stretched. Physical dimensions—thickness, width, unit area—of the product and its physical properties—unit mass and uniformity—determine the qualities sold to customers. Thermal and mechanical energy carry out the processing and can limit product footage at high roll speeds and heavy material loads.

The pie chart in Figure 1 shows that in these sheet-producing industries raw material costs absorb about 40 percent of the sales price and processing costs around 30 percent. Their sum, "cost-of-products-sold", varies from 65 to 80 percent of the sales price. Because the remaining portions of the price pie before profits—marketing expenses, administration, research and engineering, and taxes—are relatively inflexible, the search for ways to increase profits concentrates on ways to reduce raw materials waste and ways to process the materials less expensively. The control engineer can do a *little* to reduce the costs of labor, maintenance, depreciation, and expendable supplies, but he can *substantially* influence the amount and quality of product made from given quantities of raw materials and he can see to it that a major item of processing costs, the power required to drive the machinery and dry or cure the sheet, is used most efficiently. If he can prove that the automatic systems he proposes will actually, not in theory or by assumption, reduce either processing costs or raw materials waste, he can offer a realistic opportunity for enlarging the piece of the pie marked "profits". Table I summarizes net profits, in 1955-56, and the "cost-of-products-sold" of leading steel, rubber, paper, and plastics companies. Their annual reports, ARGUS INVESTMENT REPORTS BY COMPANIES AND INDUSTRIES, and MOODY'S MANUAL, are the sources of this data. Note that there is a relation between the maximum earnings of a company and its cost-of-products-sold. An operation with high product costs, say 80 cents of the sales dollar, has difficulty in realizing profits greater than 5 cents. But when a company holds down to 70-75 cents its cost-of-products-sold, as have some of the more efficient paper companies, the earnings increase to a substantial 8-11 cents.

Stabilizing or reducing cost-of-products-sold, through more efficient operation—at a time when raw material prices, labor, maintenance, and marketing costs are increasing and when manufacturers are emphasizing lower tonnage costs rather than greater production—is the technico-economic function which the control engineer can exercise directly.

TABLE I

NET PROFITS OF SOME MANUFACTURERS OF SHEET PRODUCTS
In 1955 and 1956 •

Company	Year	Total Income, $Millions	Cost of Products Sold		Net Profits	
			$Millions	Percent of Sales	$Millions	Percent of Sales
METAL:						
Wheeling Steel	1955	246.7	197.6	80.5	17.3	7.0
	1956	256.3	203.9	79.5	17.7	6.9
Sharon Steel	1955	171.18	150.70	87.5	7.99	4.7
	1956	178.68	160.93	90.0	6.91	3.9
Republic Steel	1955	1,188.6	975.0	82.0	86.3	7.3
	1956	1,244.2	1,013.9	81.5	90.4	7.3
Jones & Laughlin	1955	696.5	567.2	82.0	50.1	7.2
	1956	742.6	625.6	84.5	45.1	6.1
PAPER:						
Crown Zellerbach	1955	307.2	218.9	71.5	32.7	10.7
	1956	463.6	328.7	71.0	50.0	10.8
International	1955	799.5	607.3	76.0	83.1	10.4
	1956	974.8	764.6	78.5	86.6	8.9
Container Corp.	1955	215.6	168.8	78.5	15.7	7.3
	1956	276.0	223.3	81.0	18.2	6.6
Oxford Paper	1955	56.43	45.97	81.5	4.13	7.3
	1956	61.69	49.23	80.0	4.64	7.5
RUBBER:						
Goodyear	1955	1,372.2	1,060.9	77.5	59.7	4.4
	1956	1,358.8	1,040.1	76.7	62.5	4.6
Firestone	1955	1,114.9	857.8	77.0	55.4	5.0
	1956	1,115.2	840.3	75.4	60.5	5.4
General	1955	295.7	248.5	84.5	9.7	3.3
	1956	390.5	337.6	86.5	10.9	2.8
Mansfield	1955	74.56	65.71	88.0	1.77	2.4
	1956	61.56	53.74	87.5	1.38	2.2
PLASTICS:						
Congoleum Nairn	1955	59.759	45.388	76.0	2.246	3.8
	1956	53.448	42.607	80.0	0.728	1.4
Celanese Corp. of America	1955	177.5	140.9	79.0	15.4	8.7
	1956	188.3	147.2	78.5	16.9	9.0
du Pont	1955	1,941.4	1,150.4	59.5	431.6	22.2
	1956	1,917.4	1,212.1	63.0	383.4	20.0
Dow Chemical	1955	470.7	351.6	75.0	37.4	8.0
	1956	565.3	398.5	70.5	59.7	10.6

• Source: Moody's Industrials

less breakage on order changes, and a greater percentage of on-spec material on the last reel after order run-out all increase the capacity of the machine to make acceptable product in a unit of time and thus are, in effect, increases in machine speed. They mean process time savings.

STEP 2. Set up a simple economic model

An economic model relates product cost to material cost and processing cost. Because the economic dynamics of a continuous process are orders of magnitude slower than its technical dynamics, the economic model is effectively a steady state one except during startups and product-grade changes. Processing charges include labor, power (electric and thermal), depreciation on machinery, maintenance, supplies, and a share of plant overhead and rent. Reject and recycle rates, limited drying capacity, direct effects on the heat balance of the plant, and relationships between machine speed and product weight (see, for instance, Figure 3) are carefully studied and their influences on process economics recorded. Any one of them may be a potential source of reduction in processing costs and waste.

The economic data should also include records of typical time consumed per shift in making startup, grade, and weight changes.

STEP 3. Determine statistical distribution of key dependent variable

The key dependent variable must be the quality sold, or at least the variable directly related to this quality. It must be measurable, and controllable by an independent variable that can be manipulated by a final control element—a valve, a motor, an hydraulic actuator, a variable-speed extrusion screw, a saturable reactor, etc. Having selected the key dependent variable and its tentative measurement and control means, the control engineer next determines the distribution of its variations. The variations may be:

- Short term, frequently recurring variations that are either random or regular. Machine conditions generally cause them. For example, in processes in which the sheet is formed by passing it through rolls, an out-of-round roll will cause a cyclic variation in the sheet. A random short-term cyclic variation observed in paper processes is due to the formation of the stock. Instead of trying to control it, operators normally leave it for engineering analysis.
- Process-trend variations, defined as the gradual wanderings of an average weight or thickness from a desired target. This trend variation occurs over longer periods than the cyclic variation, is generally larger, and is one of the factors which operators attempt to control.
- Cross-sheet variations, defined as uneven weight distribution from one side to the other of the strip or sheet. They may be a function of fixed machine

An example from a study of a Fourdrinier paper mill illustrates calculation of standard deviation.

Sample, lb/ream		F	F, in % of N	D, in gauge intervals	$F \times D$	$F \times D^2$
45.5		8	0.4	−9	− 72	648
46.0	data	7	0.3	−8	− 56	448
46.5	for	6	0.3	−7	− 42	294
47.0	bar	20	0.9	−6	−120	720
47.5	chart	12	0.5	−5	− 60	300
48.0		21	0.9	−4	− 48	192
48.5		104	4.6	−3	−312	936
49.0		228	10.0	−2	−456	912
49.5		300	13.4	−1	−300	300
50.0		407	18.1	−0	0	0
50.5		415	18.5	1	415	415
51.0		320	14.2	2	640	1280
51.5		198	8.8	3	594	1782
52.0		115	5.1	4	460	1840
52.5		54	2.4	5	220	1350
53.0		15	0.7	6	90	540
53.5		6	0.3	7	42	294
54.0		5	0.2	8	40	320
54.5		3	0.1	9	27	243
TOTALS		$2244 = N$	99.7		+1112	13014

Therefore, $\Sigma FD^2 = 13014$ Standard deviation, σ

$\Sigma FD = 1112$ in gauge intervals

$$= \left[\frac{13014}{2244} - \left(\frac{1112}{2244}\right)^2\right]^{1/2}$$

$$\sigma = \pm 2.35$$

The gauge interval is taken as 0.5 lb/ream, which experience has shown to be best for analyzing weight variations in most paper and board. Exceptions are very light papers—tissue, cigarette paper, and condenser paper, for which a gauge interval of 0.25 lb/ream is more meaningful.

Since the gauge interval is 0.5 lb/ream, 2σ, in lb/ream, $= \pm 2 \times 2.35 \times 0.5, = \pm 2.35$ lb/ream.

The process mean $(\overline{X})$ is equal to:

$$\text{Assumed mean} + \Sigma \frac{(FD)}{N} \times \text{gauge interval} =$$

$$50 + \frac{1112}{2244} \times 0.5 = 50.25 \text{ lb/ream.}$$

Then the process spread is
50.25 − 2.35 to 50.25 + 2.35 or 47.90 to 52.60.

Figure 4 shows the bar chart, plotted from the first and third columns of the tabulated data.

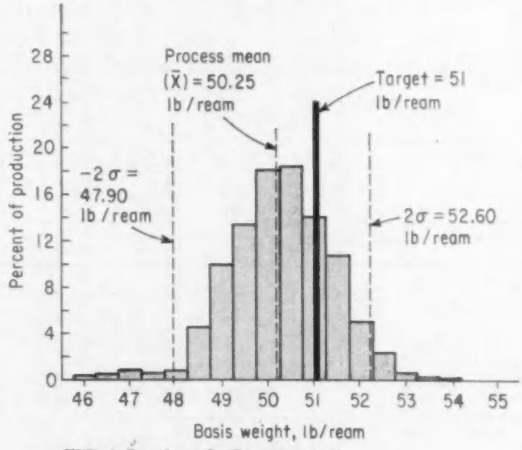


FIG. 4. Bar chart clarifies concept of statistical deviations of uncontrolled process.

characteristics or they may be a controllable process variable. In the case of sheets formed by rolling, the shape of the roll contributes to the variation and is generally not controllable. In paper-making and in the formation of sheets by extrusion, cross-sheet variation is controllable.

There are four sources of data on variations:

1. Experience
2. Sample weighings when the process produces discrete units or samples are cut out and weighed
3. Quality control and production records
4. Chart records made with a survey measuring kit

Calculation of standard deviation and the preparation of distribution curves is the best way to analyze variations. Standard deviation is a yardstick of process improvement and helps in determining process economics. For clear presentation, the frequency distribution curve (Figure 2) or the simplified bar chart (Figure 4), is recommended. The combination of standard deviation and distribution curves provides a clear-cut means of determining the net worth of a proposed control system.

Referred to as σ, standard deviation is the statistician's shorthand way of stating the limits of process variations. Plus-and-minus 1σ describes the limits that bound 66.6 percent of production, plus-and-minus 2σ bounds 9.56 percent of production, and plus-and-minus 3σ bounds 99.7 percent of production. A 100 percent sampling is not practical, but the full spread is nevertheless accounted for by the formula for calculating standard deviation, by considering that the data not taken into account has the same statistical distribution as the data that is (the few widely scattered large deviations from target that occur in any process are not necessarily indicative of a normal process spread). Plus-and-minus 2σ is the value most often used by industry. The box on page 70 illustrates calculation of standard deviation.

The formula for standard deviation is

$$\sigma = \left[\frac{\Sigma (FD^2)}{N} - \left(\frac{\Sigma FD}{N} \right)^2 \right]^{1/2}$$

where F = frequency, the number of times a data sample falls within a gauge interval. (The gauge interval chosen for the sample in the box on page 70 is 0.5 lb; i. e., 46.5 — 46.0, 46.0 — 45.5, etc.).
D = deviation from assumed mean
N = total number of data samples taken

When calculating from sample weighings or production data, the sample and frequency are taken directly from the recorded sample weights. When working with recorder charts, the sample is determined by visually averaging the recorder trace for each ½ in. of chart. This averaging smooths the effect of fast cyclic and wild short-term variations and produces a clearer picture of significant spread.

STEP 4. Predict controllability and its earning index

Table II lists typical economic returns on nuclear gauging and control systems classified according to industry and application. The returns stated are based upon actual case studies, during which complete economic evaluations were conducted during and after installation. The prices of the measurement and control systems ran from $15,000 to $100,000.

Each of a group of three case histories in the October issue will briefly demonstrate the three preceding steps, then ways of estimating controllability, and finally how to realistically evaluate the earnings of one or more of these improvements:

- greater uniformity through reduction of standard deviation
- raw materials savings through reduction of target value (tighter control permits this)
- reduction in time consumed during startups and gauge changes
- increased machine speed (possible because reduction in above-target variations and reduction in target value make available extra capacity).

TABLE II. TYPICAL ECONOMIC RETURNS ON BASIS-WEIGHT CONTROL SYSTEMS

Industry	Application	Dollar Return
		$ per year
Metals	Tandem cold roll mill (five-stand)	200,000 to 600,000
Rubber	Tire fabric calender	65,000 to 150,000
Paper	Paper making (Fourdrinier machine 160-in. sheet)	65,000 to 200,000
Plastics	Calendered sheet and film	50,000 to 150,000
Laminated plastics	Saturator dip coater	140,000
Coated abrasives	Abrasive line	96,500

Credits H. R. Chope, vice-president of Industrial Nucleonics, related to the author the principles covered by this article. W. C. Mays, western regional sales manager, and G. I. Doering, manager of the Rubber & Plastics Div., Industrial Nucleonics, furnished the application information that will appear in Part II.

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Visual Check for Taped Machine Programs

ROBERT A. BENNETT, The Martin Co. (Denver)

As progress is made in applying general-purpose computers to the preparation of programs for numerically controlled milling machines, considerable attention is being given to working out "diagnostic" or checking procedures. These procedures are directed not so much at the computer, which after all is a highly developed piece of equipment with a multiplicity of built-in self-checking features already provided. What is wanted instead are periodic checkpoints that will ascertain whether or not the computer was given the correct information initially and that the program data delivered by the computer is actually a true representation of the parts drawing.

At Martin-Denver, the IBM 704 generates control information for a GE-Giddings & Lewis skin mill. Incorporated in the computer program is an unusual diagnostic routine that produces a pictorial display of the part as embodied in the data emerging from the computer. In this routine, the cutter-offset points are plotted on IBM 740 and 780 cathode-ray-tube units during the computer run (less than 10 min for typical production parts). The operator can see immediately whether or not the program accurately represents the desired part.

Figure 1 shows the IBM 704 program devised for this application, which is based on the MIT approach (Refs. 1 and 2) but with some important innovations. There are four output formats, the first of which is magnetic tape to punched cards to punched paper tape. The latter feeds the G & L–Concord Controls Director to produce the 1-in., 14-channel magnetic tape for machine control.

During the computer run, the cutter offset points are stored on tape 5. Next, the CRT phase processes these points to plot a complete trace of the cutter center path using the tool tip as the Z-axis reference. Photographs are made with the trace operating at maximum CRT–computer speed. For visual observation, however, the trace must be slowed. This is done during a rerun of tape 5 by plotting and replotting each group of 12 successive CRT points three times. Under these conditions the persistence of the CRT face is sufficient to retain the complete trace for a long enough time for viewing by the operator.

Tape *10* records the complete machining program for off-line printing. Some months ago this printed format was copied by a typist at the G & L tape preparation desks, but this manual operation has been eliminated by the magnetic tape-to-cards and cards-to-punched-paper-tape routine. Key punch and verification of the handwritten input listing is now the only manual operation in the system.

In addition to the headings and line-by-line program in G & L machine language, the manuscript has two noteworthy features. The first algebraically sums each column of delta distances at each STOP. This enables the Director operator to verify that the correct signals are impressed on the machine control tape by comparing the Director counter registers and the manuscript column sums.

The second feature is the printing out of cut-vector velocity for each line or block of control information. A program is in work which will make use of this information to "educate" the basic numerical control program. Briefly, the data will be statistically studied by a computer program and the results will point out optimum feeds, speeds, etc., for given materials, tools and operating conditions. It is expected that this will eventually lead to "automatic planning" wherein numerical definition of part configuration, materials, finish desired and method of work holding are the

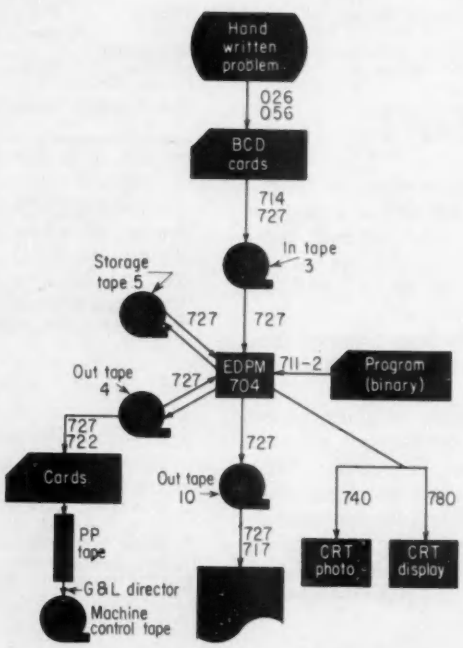
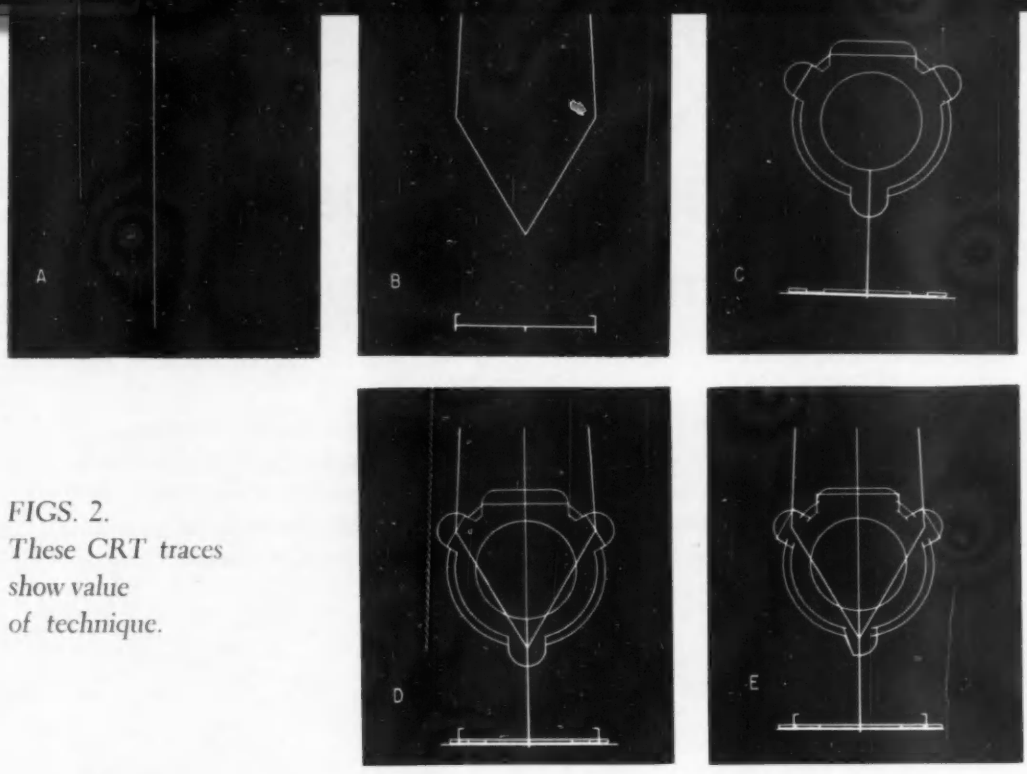


FIG. 1. Flow diagram for applying IBM 704 to milling-machine programming.



FIGS. 2. These CRT traces show value of technique.

only computer prerequisites for generating a complete machining program.

Example of display

The accompanying pictures are typical of the displays obtained on the CRT units. In this example the cutter path is traced and represents the paths the cutter will follow in the X-Y plane. In other words, the photo is a plan view of the cutter path including the tool radius offset. The bottom of the photos show a side view of the trace of the bottom center of the cutter. The side view is expanded out of proportion to the plan view because the magnitude of the Z axis motion is relatively small.

The trace in Figure 2A represents the path followed by the right and left cutter heads as they are oriented and move out to park position, across to the center of the table, and back again. Figure 2B portrays the left head coming out from park position to drill three holes in the part. Note from the side view at the bottom that after drilling the first hole, the drill rises only far enough to clear the top of the part before proceeding to the next hole. Figure 2C records the motion of the right head from park through three circle-cutting operations, with the tool plunge shown at the bottom. Figure 2D is a composite of all three sequences.

Figure 2E is a photograph of the tool path trace originally computed for the part in this example. In viewing this display, the operator detected several errors which would have caused the tool to cut off the side of one tab entirely and to cut into all of the tabs at many points. This example points up the value of the CRT analog in finding gross mistakes, such as the specification of a wrong direction or the mislocation of a point definition. The technique is not intended for precise checking of computer math. Figure 3 shows the part used in this example during the subsequent milling.

After successful completion of the computations for a program, the only assurance that it will be properly recorded on the machine control tape is the monitoring of the Director counters. To-date, this has proved adequate, except that human (operator) errors still occur. Equipment capable of making a similar trace from the machine control tape would solve this problem. Several companies are considering various approaches to this problem.

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2. *AUTOMATIC PROGRAMMING OF NUMERICALLY CONTROLLED MACHINE TOOLS*, Arnold Siegel, "Control Engineering", October 1956.

FIG. 3. Example part being machined on G & L skin mill.



Improving Performance of Flat-Armature Torque Motors

The fast response and high resolution inherent in the flat-armature torque motor account for its increasing popularity as an actuator in applications such as servovalves, remote positioners, and tape seekers. Described here are special techniques and drive circuits that enable the designer to get even better response and resolution characteristics from the torque motor.

R. D. ATCHLEY, Raymond Atchley, Inc.

Flat-armature torque motors are small electromechanical transducers, Figure 1, designed to convert a small differential current into a proportional mechanical force. The field structure of a typical motor consists of two C magnets arranged in opposition, as shown in Figure 2. The armature is a bar mounted on two flexure "bearings" that not only furnish support but also act as torsion springs restraining the rotation or pivoting of the bar. Each of the two coils on the armature is wound in an opposite direction and connected to an individual pair of control terminals.

With no current in the coils and the armature centered, the polarizing flux supplied by the magnets assumes the path shown by the solid lines on the diagram in Figure 2. If a differential current is applied to the coils, a net magnetic field or "control flux" is produced in the armature and takes the path shown by the dotted lines. Part of the polarizing flux then follows the same path and reinforces the control flux. Thus, the density of magnetic flux increases in two of the four air gaps and decreases in the remaining two. The unbalanced flux distribution causes a clockwise torque to act on the armature. Because the armature is spring restrained, it then rotates to a position where the clockwise torque exerted by the motor equals the counterclockwise centering torque produced by the torsion spring in the armature support.

Figure 3 shows a displacement vs. differential current plot for a typical torque motor. The stiffness of the centering spring is adjusted so that when the motor is unloaded, about 35 percent of maximum rated current will produce full stroke. With the centering spring adjusted to this value, approximately one-half of the midposition torque is avail-

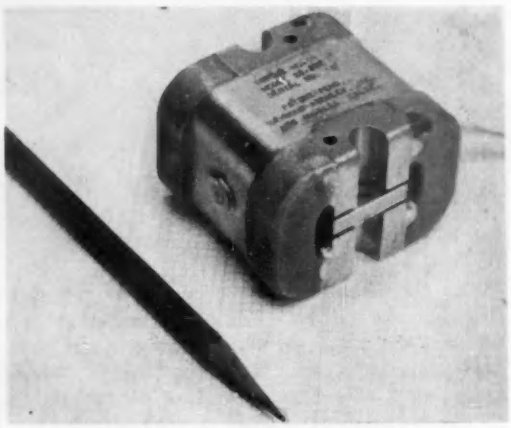


Fig. 1. Torque motor shown produces a midposition force of 13 lb, weighs only 20 oz.

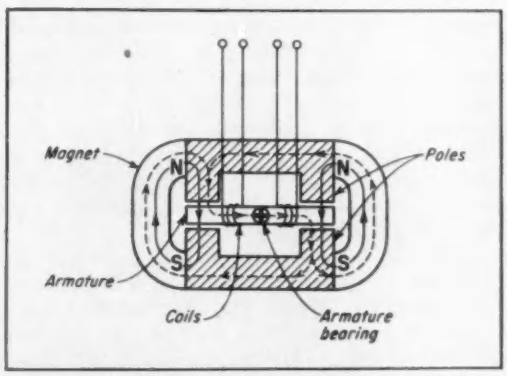


FIG. 2. Schematic cross-section diagram of torque-motor construction.

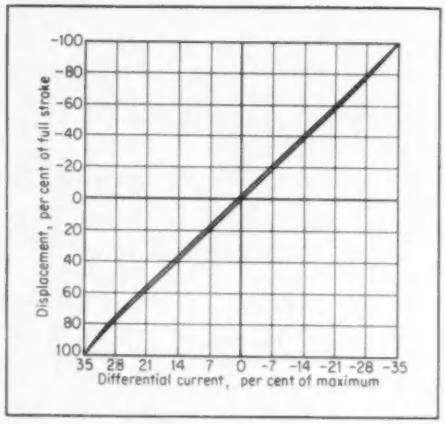
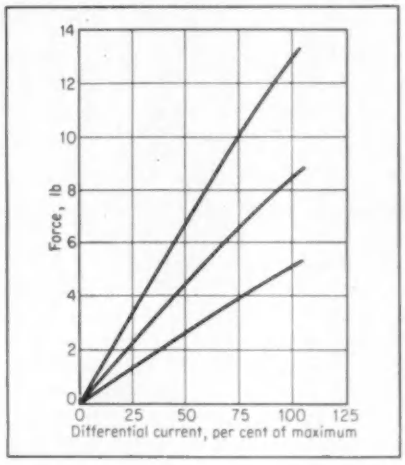


FIG. 3. *Plot of displacement vs. differential current shows hysteresis effects.*

FIG. 4. *Relationship of midposition force to differential current for three standard models of torque motor.*



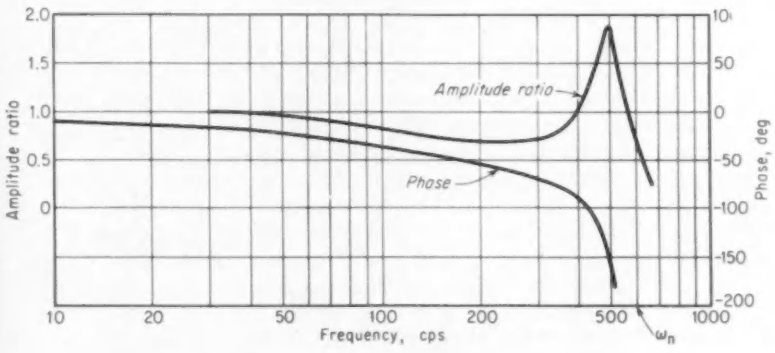


FIG. 5. *Dynamic response characteristics for torque motor loaded with a small pickoff. The unloaded natural frequency (marked) is above 600 cps.*

able at full stroke to move a load in the direction of displacement. Figure 4 shows a typical plot of midposition force vs. differential current.

The displacement sensitivity of the torque motor does not change appreciably even after millions of cycles of operation. However, environmental temperature changes cause the flux of the magnets to vary and thus may temporarily affect displacement sensitivity. The effect of temperature variations on force sensitivity is about one-fifth as much because the positive mechanical spring constant and the negative magnetic spring constant of the motor have a ratio of about five to four. The sensitivity is independent of the quiescent current in the coils.

Efficient torque motors, because of the very low inertia of the rectangular armature, have natural frequencies of several hundred cycles per second. Thus, torque motors require no damping because this value of natural frequency is usually very high compared to that of the system in which they are used. Since the armature is supported by a frictionless elastic torsion member, the resolution of the torque motor is virtually infinite. If the armature were supported by sleeve or ball bearings, the resolution would be lower because some of the output signal would be consumed in producing the breakaway torque needed to overcome the static friction on the armature.

A feature of the flat-armature torque motor is an extremely high torque-to-inertia ratio compared to that of small rotating electric motors. In addition, the magnetic force on the armature acts perpendicularly to the radius and not at a low angle, as in a round-armatured spring-restrained electric motor. These factors insure fast dynamic response.

Figure 5 shows dynamic-response characteristics of phase and amplitude vs. the frequency of the applied signal. These curves are for a torque motor with 2,000-ohm coils driven by two high-impedance 6AQ5 vacuum tubes in push-pull. Lower impedance coils should be used in torque motors driven by transistors or magnetic amplifiers. For best response characteristics, the torque motor should be driven with as much current as the driving source will produce. It is thus advisable to specify the lowest practical values for the impedance of the armature coils. When the ratio of driving source impedance to torque motor impedance is too low, the system phase lag is increased and the amplitude response is reduced. At the same time, however, the system damping is increased.

Torque motor applications

Torque motors are used primarily to actuate hydraulic or pneumatic servovalves. In such applications, electronic, magnetic, or transistor servoamplifiers furnish the driving power. The amplifiers usually operate in push-pull to minimize drift resulting from changes in the torque-motor coil resist-

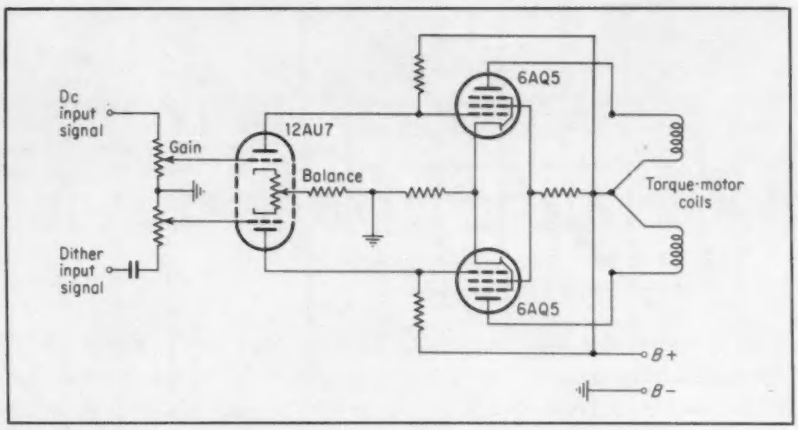


FIG. 6 Electronic driving circuit for torque-motor applications.

ance caused by temperature variations. Figure 6 shows a typical electronic torque motor driving circuit. In servovalve applications, the torque motors most often drive small hydraulic or pneumatic preamplifiers, which in turn actuate a second power stage. Larger torque motors may drive the power stage directly if the system power output is small and if the pressure of the medium is low.

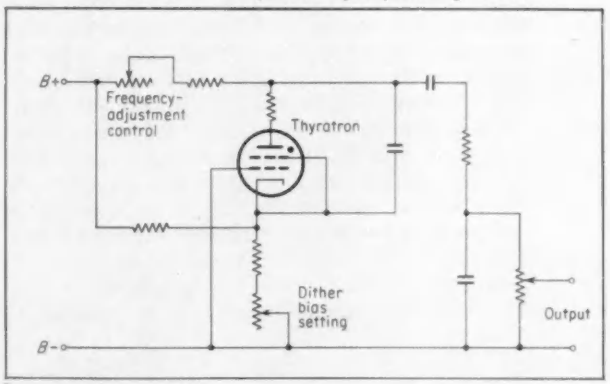
Older hydraulic servovalves were actuated by spring-restrained dc electric motors, which had high inertia, poor resolution, and low efficiency. In recent years the flat-armature torque motors, similar to those described in this article, have been used almost exclusively to drive servovalves. They are compact and have low inertia, excellent resolution, high efficiency, and low weight. Although the stroke of the flat armature is limited to a few thousandths of an inch, this does not usually constitute a handicap because servovalves are themselves short-stroke devices. For applications requiring longer strokes, mechanical linkages are used to amplify the torque-motor stroke.

Spring-restrained solenoids or translational-type force motors are sometimes used to drive servovalves. Unless such actuators are polarized by permanent magnets, however, their efficiency is considerably lower than that of the rotating armature type of torque motor. These devices do not produce as high a force and as long a stroke as does the torque motor for the same input power. In addition, their output is affected by lateral accelerations.

Dither, often used to improve the resolution of servo systems, is a high-frequency (usually sinusoidal) input to the torque motor. It continuously agitates the system parts, such as the second stage valve piston or output ram, which may tend to stick and not respond to small input signals. A properly chosen dither frequency does not cause undesirable resonance in any part of the system and is sufficiently high (usually several hundred cycles per second) so that the load actuator will not respond enough to cause undue wear in the high-power mechanical parts of the system. The optimum dither frequency must be selected experimentally, because it is difficult to try to predict the frequency at which the various system components might resonate. System parts most likely to be resonant because of low inherent damping are: steel tubing (oscillating axially or radially), columns of oil that may resonate by themselves, and volumes of oil that act as the spring in a spring-and-mass system in which the mass is the combination of the load and the load actuator (a hydraulic cylinder or motor). In Figure 7 is shown a circuit diagram of an adjustable frequency dither generator. This dither signal is introduced into the servoamplifier immediately after the dc summing circuit and is superimposed on the control signal.

Torque motors have been used also in closed-loop position servos to position accurately and in optical systems to modulate a light source. Position repeatability of plus or minus 0.0003 in. can be attained with an output stroke of plus or minus 0.030 in. The components in a typical closed-loop positioning system are a servoamplifier, a torque motor connected to the member to be positioned, and a frictionless pick-off, such as a linear variable differential transformer, for feedback. The input signal may be a dc voltage in the forward path or an ac voltage

FIG. 7. Circuit for adjustable-frequency dither generator.



to the servoamplifier demodulator. Either type of input voltage may be obtained from potentiometers for signal adjustability.

It is not possible to obtain such high positioning accuracy from torque motors without closed-loop operation, because of torque motor hysteresis. With closed-loop operation, the load-position measuring device detects all position errors, including those caused by torque motor hysteresis. The feedback signal causes the servoamplifier to drive the torque motor in the proper direction to remove the error. System errors are removed by a factor of approximately one over the loop gain in the servo system. Loop gains from 10 to 100 may be achieved in closed-loop servo systems of this type.

Another use for flat-armature torque motors is as tape seekers in computers. Here the torque motor armature moves a small roller located a few thousandths of an inch away from a capstan pulley that is driven at a constant velocity of several thousand rpm. The magnetic tape is threaded between the roller and the capstan. When the torque motor is energized, the tape is instantaneously forced against the capstan, which then begins to pull the tape at high velocity.

Fast-response circuit

The primary source of delay in the response of a torque motor to an input signal is the inductive reactance of the coils, which tends to impede fast current changes. To obtain the fastest possible response for this type of operation the motor is connected in parallel aiding and is driven by a thyratron tube connected in series with a capacitor charged to a high voltage. Torque motors driven in this manner have achieved response times of approximately one millisec.

The schematic diagram for a fast-responding thyratron circuit is given in Figure 8. The operation of this circuit is as follows. Initially, the thyratron is not conducting. Capacitor C is charged through the current-limiting resistor to full voltage. The cathode of the thyratron is tapped off at a point on the bleeder resistor so that sufficient negative bias is applied to the thyratron to prevent self-firing. The torque motor coils are connected in parallel aiding between the plate of the thyratron and capacitor C. When a positive pulse is applied to the grid, the thyratron fires, effectively connecting the charged capacitor C across the torque-motor coils. The energy stored in the capacitor at high voltage quickly discharges through the torque motor, causing the motor current and output force to increase rapidly.

When the capacitor is completely discharged, the magnetic field of the torque motor collapses and the inductive energy stored in this field charges the capacitor in the opposite polarity. The plate potential of the thyratron is reduced to such a low value that conduction ceases and the thyratron is reset to its initial nonconducting state. Capacitor C draws current from the power supply through the current-limiting resistor until it is fully recharged. The system is now ready to fire again.

In this application, the torque motor coils are conected in parallel aiding to increase the motor efficiency and to reduce its inductance. In applications where efficiency is important and only low currents are available for driving the torque motor, the coils may be connected in series aiding.

Control circuitry

One important characteristic must be recognized when designing the electrical circuitry for driving torque motors: they are current-operated devices. Torque motors produce an output force that is proportional to the net ampere-turns in the electromagnetic circuit. Since the coil turns in any given unit are fixed, the net output force is proportional to

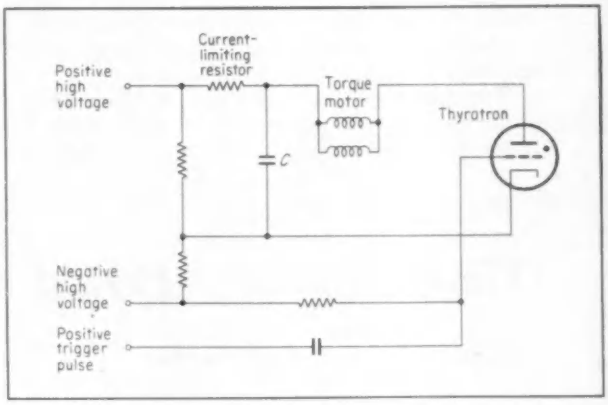


FIG. 8. Thyratron driving circuit for fast-response applications.

the current through the coils. For best dynamic performance, the torque motor should be driven with the maximum current available from the driving source so that the coil resistance (and inductance) will be at a minimum. In other words, the ratio of driving-source impedance to a torque-motor impedance should be as high as possible.

Torque motors are available with coil resistances varying from a few ohms to several thousand ohms. The selection of coil resistance depends upon the current capacity of the driving source. Since the maximum input power of any torque motor is constant, coil resistance can be easily calculated.

The coil resistance changes appreciably with temperature variations. To minimize drift under adverse temperature conditions, the torque motor should be driven in push-pull. Pentode or beam tetrode vacuum tubes (similar to the 6AQ5) are frequently used in the push-pull output stage of electronic servoamplifiers to drive torque motors. Because of

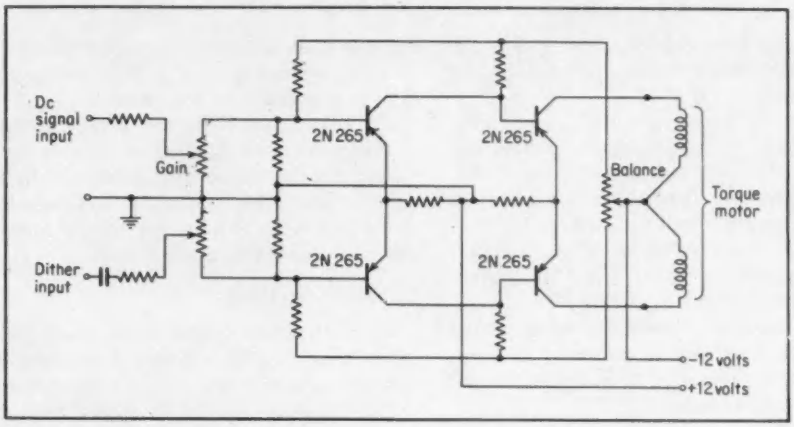


FIG. 9. Transistorized version of torque-motor power supply.

their lower plate impedance, triodes should not be used if speed of response is important. Common-emitter transistors connected in push-pull are also satisfactory because of their high collector impedance. Figure 9 shows a schematic diagram of a typical transistor driving circuit that is the equivalent of the electron-tube circuit in Figure 6.

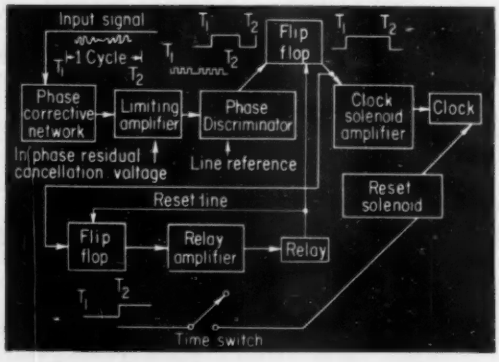
Magnetic-amplifiers have been widely used for both military and industrial servo applications because of their excellent reliability. The speed of response of the magnetic amplifier, however, is sometimes too low for certain high-performance servo systems. The excitation frequency and the required amplifier gain generally determine the maximum speed of response of the amplifier. Thus, there is indication that, at least for torque-motor systems, magnetic amplifiers in aircraft will probably be replaced with fast-responding, low-weight transistor amplifiers as soon as the latter can be made to operate reliably at higher temperature.

Timer Measures Period of Servo Oscillation

JAMES COLKER, I. W. Fecker, Inc.

In servo systems, it is often necessary to measure the period of oscillation of an output shaft. A simple and convenient means to do this has been developed by I. W. Fecker, Inc., for use on a three-axis flight simulator and other servo devices of their manufacture. An ac tachometer, resolver or synchro mounted on the shaft under test provides the input to the measuring circuitry. The unit automatically times one full oscillation or one complete revolution of the shaft and then presents the measured value by means of a clock display.

In operation, the signal from the tachometer or resolver is phase-corrected and amplified. The amplifier stage changes the sinsoidally modulated 60-cycle suppressed-carrier signal into a square-wave modulated 60-cycle suppressed-carrier signal. The phase correction brings the signal exactly in phase with line frequency. The signal is then passed to a phase detector, which reproduces the square wave envelope of the modulated carrier.



With the detector referenced to the line phase, quadrature signals are rejected.

The next step is differentiation of the square-wave envelope, producing two negative-going triggers per cycle. These triggers are passed to a bistable multivibrator to generate a square wave having a positive-going pulse. The pulse, whose duration equals the period of the signal to be measured, moves through an amplifier to a clutch on a clock mechanism accurate to plus or minus 0.005 sec.

Another portion of this square wave is differentiated and passed to a second multivibrator that generates a positive-going pulse as soon as the pulse produced by the first multivibrator (feeding the clock) goes in the negative direction. This positive pulse pulls in a relay, stopping the multivibrator counting circuit. Thus, the clock will time only for one period of oscillation before it is shut off. When a spring-loaded switch is depressed, the counting circuitry is started again and the reset solenoid of the clock is energized at the same time.

Get Maximum Accuracy from Your Dip-Tube Level and Density Systems

M. J. Kelly, ORNL, Oak Ridge, Tenn.

Despite their wide industrial use for level and density measurements, little has been published on the factors that affect the accuracy of dip-tube systems. This Data File, summarizing the results of an extensive survey made at the Oak Ridge National Laboratory, lists these factors and shows how each contributes to overall accuracy.

How they work

Figure 1 illustrates the principles of dip-tube density measurement. A slow gas flow through each tube forms bubbles at the immersed ends, which break away and rise to the surface. Effectively, then, a column of gas exists in each tube. The pressure needed to maintain this gas column depends on:

1. *depth of immersion*
2. *specific gravity of the fluid*
3. *specific gravity of the gas*
4. *surface tension of the fluid*
5. *viscosity of the fluid*

In a symmetrical system for measuring density, the last two factors, surface tension and viscosity of the fluid, contributed equally to the total pressure in each tube. Thus they have no effect on differential pressure and may be neglected. Except at high pressures, the specific gravity of the gas may also be neglected.

Level-measuring systems, however, require only one tube and the effects of viscosity, surface tension, and density of the fluid must be taken into consideration. Extremely viscous fluids cause a false back-pressure increase when a bubble forms rapidly. In a typical level-measuring system, a bubble rate of not more than 30 bubbles per min produces no noticeable effect until the fluid viscosity exceeds several hundred centipoise.

Density and surface tension combined produce an added back pressure known as dip-tube bias. This can be determined experimentally for water and then for any other liquid by using the equation

$$P_s = \frac{\gamma_s d_s}{\gamma_{H_2O} d_{H_2O}} P_{H_2O}$$

where P_s represents the bias correction of the fluid being measured, γ the surface tension, d the specific gravity, and P_{H_2O} the bias observed for water. This correction seems to hold for all Newtonian systems.

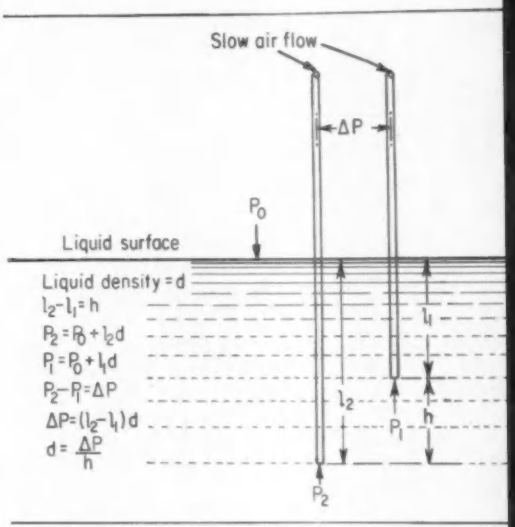


FIG. 1. Simplified sketch of a dip-tube system for density measurement.

Best tubes are square cut

Each curve in Figure 2 represents a different tube configuration. In general, the square-cut tube produces the most uniform wave. Since it also holds its maximum pressure value for a longer part of the cycle, it is better suited for manometers or differential pressure transmitters. The tube with peripheral holes might prove more suitable in agitated solutions, since bubble release occurs at maximum surface tension.

It is also important that the tube configuration does not affect the accuracy of spacing (dimension h, Figure 1). In density measuring systems, unless this dimension is known within 0.1 percent, other precautions become worthless.

Use short lines and balanced flows

For a good density measuring system a small change in the air flow rate should not introduce an

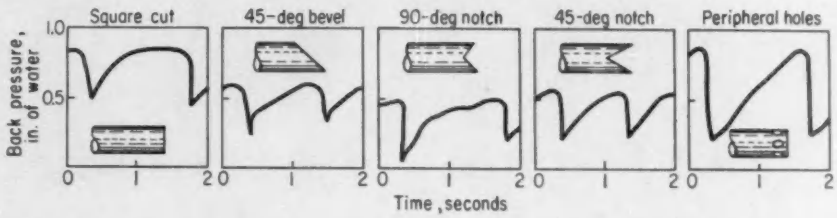


FIG. 2. Back-pressure waveforms depend on the shape of the dip tube.

error of more than 0.01 in. of water at the differential pressure transmitter. Small flow rates, short tubing lines, and balanced air flows are not just desirable. They are mandatory. Any differential in the air flows will cause considerable error due to line losses. The following recommendations cover a typical density system:

- lines—$\frac{3}{8}$ in. tubing, not over 100 ft
- gas flow rate—0.1 scfh
- dip tubes—$\frac{3}{8}$ in. tube or $\frac{1}{8}$ in. pipe

In addition, the supply lines must have similar flow characteristics. If it becomes impractical to limit a system to these conditions, the effect of pressure drop in the supply lines can be eliminated by using a two-tube system. Here one line supplies purge air to the dip tube, while the other leads back to the manometer or differential pressure transmitter. Since no flow exists in this second line, there can be no pressure drop. Effectively, the line serves as an r-c filter by minimizing pressure pulsations.

Precision of the complete system

So far this discussion has dealt with the primary element alone. To determine overall accuracy, however, it is necessary to consider all the equipment in a given system.

Where reasonably low pressures and pressure differences are involved and no record is required, a suitable manometer will suffice. However, for a permanent record at any pressure, the system requires equipment similar to that shown on the right hand side of Figure 3. This setup suits both level and density systems.

In level systems with the most careful installation of the primary element, error will seldom be lower than 0.75 percent of maximum level.

Errors which calibration cannot eliminate result from:

- hysteresis effects in the transmitter and recorder
- back pressure variations caused by solution changes
- misreading the recorder chart

The sum of these errors alone would be at least 0.5 percent of the maximum level.

In density measuring systems overall system error can be reduced by:

- Canceling the effects of bubble formation by using a symmetrical system.
- Suppressing the range of the differential pressure transmitter to indicate only changes in density.

Figure 3 shows an equipment arrangement for testing the maximum accuracy of density systems. A large vertical tube spacing is recommended for two reasons. First, the specific gravity span of the fluids under test, multiplied by the vertical spacing, gives the differential pressure span in inches of water; this must not be lower than the minimum satisfactory span of the differential pressure transmitter. Second, a large vertical spacing can be made with minimum percentage error. The manometer, used as a standard, can be read with the cathetometer to within 0.005 cm. Precision hydrometers will determine true specific gravity. For high resolution, and to minimize the effects of density change in the purge gas, the average immersion depth of the paired dip tubes should not vary by more than 3 equivalent ft of water from the calibration of depth.

In summary, dip-tube level-measuring systems, properly installed, can be expected to have an overall accuracy within 0.75 percent of maximum level. Density systems, under the same conditions, may be accurate within 0.33 percent.

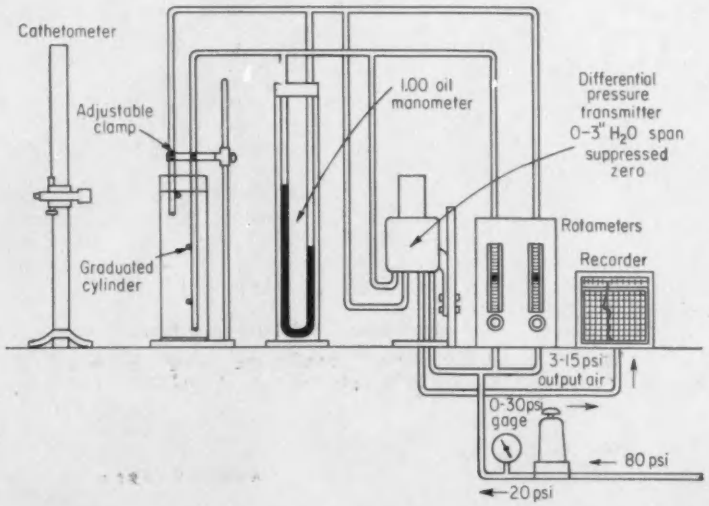


FIG. 3. Laboratory setup for testing reproducibility and precision.

Five Examples Show Versatility of Automatic Testing Systems

L. S. KLIVANS, Radioplane, a Division of Northrop Aircraft, Inc.

THE GIST: Automatic testing systems find two main areas of use: the field testing of complex control systems, and the production line testing of anything from a simple component to a major subsystem. Automatic field testing is often easy to justify: there may not be any other feasible way to do a job because of the compounding factors of complex systems, limited test time, and unskilled personnel. Integrated automatic go/no-go test sets are a must for satisfactory performance verification. For this reason many missile and aircraft checkout systems have been developed (see "The Functions of Guided Missile Checkout Systems", CtE, April 1958, p. 98).

In the factory, test and inspection often consume a large portion of the overall production time. And if the actual production process itself is under automatic control, why shouldn't the test process be also? Many of the techniques used to check out weapons systems in the field can be transferred directly to the test of installed industrial control systems, or to production line applications.

Author Klivans describes five automatic testing systems that will check out various electronic and electromechanical devices and systems from an individual relay to a complete cruise autopilot system. Most of the test system components are commercially available—the source and characteristics of each are listed. Note that tester flexibility is a common denominator: each system has some kind of easily variable programmer so that it can test many similar, but different, devices. See if you can't adapt some of these techniques to the test and inspection of your product.

Modern weapons systems consist of a large number of highly complex interdependent subsystems, each containing several major assemblies. To successfully accomplish its mission, each element in the system must precisely perform its function in accordance with the overall pattern. The interdependence factor also forces closer regulation of the allowable tolerance of each subsystem and major assembly, which in turn means that more accurate and comprehensive test techniques and equipment are required in the field and on the production line.

Most of the precise test equipment available today consists of laboratory-type instruments that must be used by highly skilled and conscientious operators. These technicians deduce in what portion of a system a malfunction occurred by interpreting test results. Considerable training is often required to familiarize the operator with the test equipment and the system being tested.

It would be better if an automatic test set ran through the necessary static and dynamic checkout tests for every portion of the system, yielding a go or no-go indication as each individual test is completed. This would remove the judgment factor, and relieve the operator of the task of correlating data to decide whether a given parameter is within tolerance. Many automatic test sets are being used to check out weapons systems today, and similar techniques are finding use in production.

What are the factors in selecting a test set?

There are seven major interdependent factors that influence the configuration of an automatic testing system: purpose, accuracy, time availability, reliability, flexibility, environment, and cost. The order of importance varies with application, and in many cases the definition of one factor may dictate the requirements of the remaining factors.

Purpose—A test determines whether or not a particular system or device is ready to be used, can continue to be used, or must be repaired. All of the parameters to be checked must be defined and correlated.

Accuracy—Accuracy normally pyramids as the complexity of the test increases, starting with very tight tolerances for the major assemblies and gradually widening so that the test may be only qualitative for a complete system test; i.e., the control system moves right or left, the conveyor belt moves faster or slower.

Time availability—The time that is available for a complete test sequence depends on the end usage of the system being tested, and on the system's dynamic

characteristics. This factor is all important in the case of a tactical or strategic weapons system, and reduces in importance for a drone system used in training or for the average industrial control system.

Reliability—This can be defined as the length of time a system will operate without failure under actual field or factory conditions. While reliability is important, it is interdependent with time availability and cost. If time is not at a premium, reliability may not be either: a testing system can be designed to be less reliable at far less cost, but still be easy to maintain.

Flexibility—A completely flexible system is one that can test any industrial control system or military weapons system. This is not possible, of course, but one testing system can test classses of devices and systems by using flexible programmers which accept instructions from selector switches, punched cards, or punched tape. In most existing checkout equipment, flexibility is minimized and each tester is tailored to handle a particular model of a system. Cost and flexibility thus are often contradictory selection factors.

Environment—Where and under what conditions the tester must operate. Considerations are temperature, atmosphere, vibration, shock, humidity, etc.

Cost—Cost is heavily influenced by each of the previous factors. On the debit side are the development, production, and maintenance expenses, while the credit side shows the savings from increased testing speed and accuracy, plus the intangible benefits of reductions in damage, inventories of spare parts, etc.

Typical testing systems

The following describes five automatic systems for testing electromechanical and electronic systems and devices ranging from a relay to a complete cruise autopilot system. Although each system has a particular purpose, the techniques are general and can be used in other applications. Commercially available sources of equipment are listed where possible. Although only one source is listed for each item, in many cases equivalent products are marketed by several other companies.

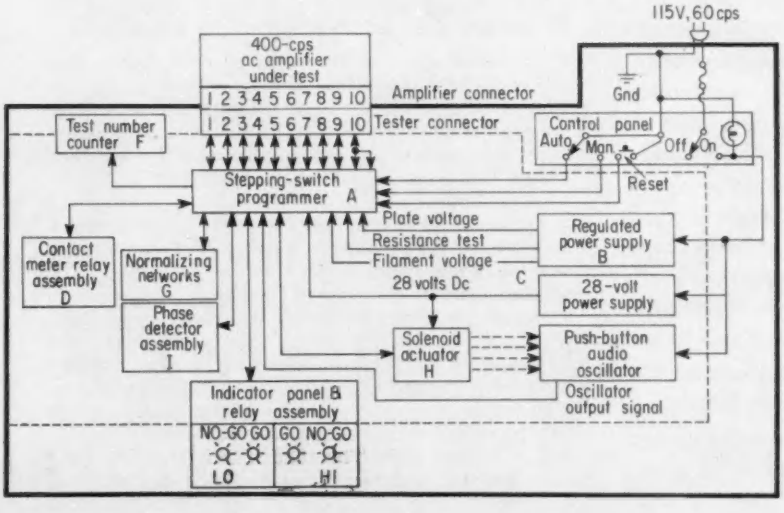
1—AC-AMPLIFIER TESTER

What the Tester Must Do

1. Verify that the proper resistance exists between each connector pin and ground with the amplifier not operating.
2. Verify that the proper plate- and filament-power-supply currents are being drawn with the amplifier input grounded.
3. Determine that the following characteristics are within prescribed limits: gain at 400 cps, 20 cps, 1,000 cps, gain linearity at 400 cps, saturation level at 400 cps, null level, phase shift at 400 cps.

How the Tester Does It

Test Requirement 1—The stepping-switch programmer selects pins one through nine of the amplifier connector in turn, each time applying a test voltage from the regulated power supply. This voltage induces a current that flows to ground through the contact meter relay assembly and a normalizing network. The normalizing network adjusts circuit resistance so that the same current flows for each pin if the pin-to-ground resistance is in tolerance. If the resistance is correct, the meter centers and a go signal is displayed. If out of tolerance, either a no-go-hi or no-go-lo signal appears. Between each test the indicator displays no-go on both hi and lo, providing a fail-safe self-test of the programmer and indicator.



Test Requirement 2—The programmer inserts a normalizing network and the contact meter relay in series between the amplifier being tested and the regulated power supply. Again, the normalizing network adjusts resistance so that the meter centers when the parameter being tested is on tolerance. The plate and filament currents are tested separately. The indicator panel functions as above.

Test Requirement 3—The programmer energizes the solenoid actuator to select the proper oscillator frequency, and controls input signal magnitude through a normalizing network. The oscillator drives the amplifier input, while amplifier output is connected to the contact meter relay assembly through a normalizing network. The test continues if a go signal appears on the indicator panel. The null-level test is conducted in the same manner, using the contact meter relay with amplifier input grounded.

In the phase shift test, the phase detector produces a positive or negative voltage proportional to amplifier phase deviation from the center value prescribed in the test requirements. This voltage is applied to the meter relay, with the tolerance band preset to agree with specifications.

Extending the Tester

By furnishing interchangeable plug-in programmers and normalizing network assemblies, the designer could make this basic system flexible enough to handle a large variety of ac amplifiers.

THE AMPLIFIER TEST-SYSTEM COMPONENTS

Item	Classification	Vendor	Part number	Approximate cost	Description
A	Rotary selector switches	G. H. Leland, Inc. Dayton, Ohio	BD3E circuit selector	$20 to $30	Basically a power-operated rotary switch intended for remote control of predetermined circuit patterns. Many versatile designs of stepping, counting, latching, and circuit-selecting relays are made possible by combining Ledex rotary solenoids and wafer-type rotary switches. The Ledex solenoid itself is available with starting torque outputs of 0.2 to 54 in.-lb. Input is dc.
B	Regulated power supply	Hewlett-Packard Co. Palo Alto, Calif.	Model 712 B	$365	Provides four voltage outputs: 0 to +500 volts, 200 milliamp maximum load; −300 volts, 50 milliamp maximum load; 0 to −150 volts, 5 milliamp maximum load; and 6.3 volts, center-tapped, 600 cps, 10 amp maximum load. Regulated to produce less than 50-millivolt change from no-load to full load on any voltage range.
C	28-volt power supply	Universal Electronics Co. Santa Monica, Calif.	Model U32-10	$525	Magnetic amplifier dc power supply with output voltage adjustable from 0 to 32 volts and a load range of 0 to 10 amp. Regulation is ±1 percent for all line or load conditions and maximum ripple is 0.25 percent. Responds to load changes in less than 0.2 sec.
D	Contact meter relay	Assembly Products, Inc. Palm Springs, Calif.	Model 455-C	$50 to $125	Indicating meter with built-in relay contacts. Contact settings are adjustable to any point on meter scale. Contact arrangements are single (high or low) or double (high and low). Ranges are available from 0 to 5 microamp to 0 to 50 amp, or 0 to 6 millivolt to 0 to 500 volts, in either ac or dc except under 250 millivolts due to rectifier limitations. Locking contacts prevent chatter and damage to contacts; built-in self-interrupter breaks locking action. Normal interruption rate is one per sec, but rates up to 25 per sec have been used successfully. Model listed is ruggedized sealed version recommended for severe environments. It can be used directly as an analog comparator if desired percentage tolerance can be kept constant for several tests at a time. Contacts then give a direct go/no-go and lo/go/hi visual and electrical readout.
E	Frequency generator	Teletronics Laboratory, Inc. Westbury, N. Y.	Model TO-100A	$345	Pushbutton audio oscillator with 20 preset frequencies in range 20 cps to 100 kc. Calibrated output control permits 1 to 25 volts per circuit with constant level within 1 db over frequency range. Remote control provisions are required if it is to be used as a digital-to-frequency generator.
F	Counter	Production Instrument Co. Chicago, Ill.	DP1A-ECS	$47.25	Four-digit electrically-operated counter with a 200-million count life. Normal maximum speed is 1,000 counts per min. Input power is 5 watts. Various coils are available from 6 to 150 volts dc, and 12 to 230 volts ac.
G	Normalizing network	Custom built		Not specified	Simple resistance-divider network on a plug-in terminal board.
H	Solenoid actuator	Custom built		Not specified	Mechanically attached to frequency generator to permit remote selection of audio frequencies upon receipt of electric commands from the stepping-switch programmer. Uses 28-volt plunger-type solenoids.
I	Phase detector assembly	Custom built		Not specified	One-tube demodulator with fixed input-voltage magnitude and a fixed phase carrier frequency. Dc output is calibrated in terms of the phase shift of the input signal with respect to carrier.

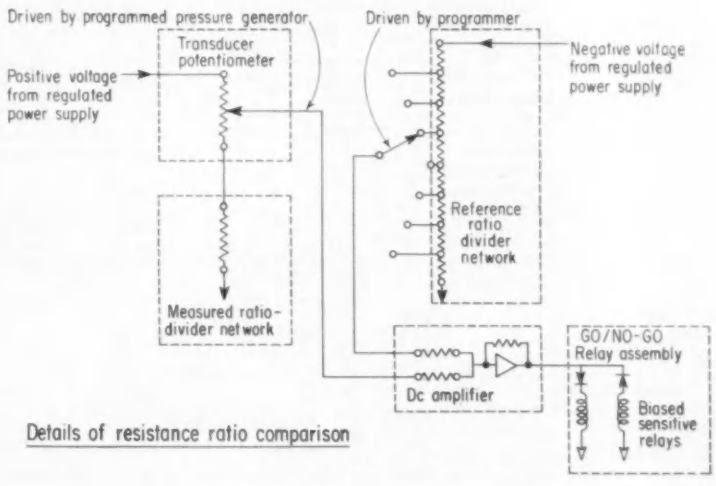
2—ABSOLUTE-PRESSURE TRANSDUCER TESTER

What the Tester Must Do

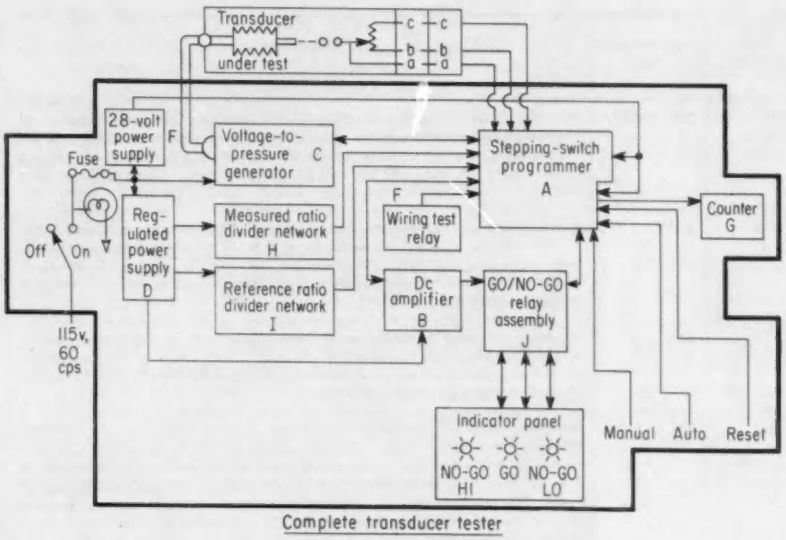
1. Verify that an open circuit exists between each transducer connector pin and the transducer case.
2. Verify that the total resistance of the transducer potentiometer is within prescribed limits.
3. Verify that the resistance ratio of the transducer potentiometer is within prescribed limits at each of ten specified input pressures.
4. Verify that transducer resolution is within prescribed limits.

How the Tester Does It

Test Requirement 1—The stepping-



Details of resistance ratio comparison



Complete transducer tester

switch programmer individually connects the wiring test relay to each pin of the transducer connector. If any pin in the connector has less than a predetermined leakage resistance to the transducer case the test relay is energized. This unbalances the input to the dc amplifier and causes the go/no-go relay to register no-go.

Test Requirements 2 and 3—The programmer actuates the voltage-to-pressure generator, sets the reference-ratio and measured-ratio dividers (which, as shown in the detailed wiring diagram, are plug-in precision resistor divider networks), and connects the transducer potentiometer output and the reference-ratio divider network into the dc amplifier. If transducer

THE TRANSDUCER TEST-SYSTEM COMPONENTS

Item	Classification	Vendor	Part number	Approximate cost	Description
A	Rotary-type stepping switch	Automatic Electric Sales Corp. Chicago, Ill.	Type 45	Depends on contacts; $80 for typical unit with gold contacts	Rotary-type solenoid-actuated switch for use on ac or dc. Twelve or more bank levels of 25 points plus "home" can be assembled on a single-sided open-type frame. Each bank level has a corresponding wiper level driven by a 52-tooth ratchet wheel. Specified speeds are 75 steps per sec self-interrupted, or 35 steps per sec impulse-controlled. Life tests have exceeded 250 million operations. Gold contacts are recommended for low-level signal switching.
B	Dc amplifier	Electrol, Inc. Los Angeles, Calif.	Model 1-A	$50	High-performance direct-coupled computer-type amplifier packaged into a chassis mounted plug-in assembly. Open-loop gain is 40,000 and drift is less than 20 millivolts referred to input grid. It will swing ±120 volts into a 10,000-ohm load.
C	Voltage-to-pressure generator	Husan, Ltd. Santa Monica, Calif.	MK-1	$22,500 (other units $15,600 to $45,000)	Dual pressure generator automatically programs 60 dual pressures to a system accuracy of 0.05 percent of better, full scale of the individual pressure range. The programmer module plugs in and can be readily replaced to suit test requirements. The generator contains two voltage-to-pneumatic-pressure servoamplifiers. Pressure sensors are of the force-balance type. Pressure input to unit is normally 5 psi above range and 3 in. of vacuum below range. Power input is 115 volts, 400 cps, single phase, 1,350 watts unregulated and 250 watts regulated. Unit is packaged to meet requirements of MIL-7-945.
D	Regulated power supply	Hewlett-Packard Co. Palo Alto, Calif.	Model 712 B	$365	See Item B under amplifier tester.
E	28-volt power supply	Universal Electronics, Santa Monica, Calif.	Model U32-10	$525	See Item C under amplifier tester.
F	Line-operated relays	Union Switch & Signal Div. Westinghouse Air Brake Co. Swissvale, Pa.	R35FP6A	$27.50	Miniature hermetically-sealed 26.5-volt relay. Coil resistance 225 ohms. Contacts are six-pole double-throw. Either standard or dry circuit contacts are available. Standard contacts rated at 100,000 operations; 2 amp resistive or 1 amp inductive. Dry contacts rated at 100,000 operations; low-level dry circuit loads up to a maximum of 1 amp resistive or 0.5 amp inductive. Pull-in time—15 millisec; dropout time—6 millisec.
G	Counter	Production Inst. Co. Chicago, Ill.	DP1A-ECS	$47.25	See Item F under amplifier tester.
H	Measured ratio-divider network	Custom built		Not specified	These three items must be developed: all are simple networks as shown by the detail of resistance ratio comparison.
I	Reference ratio-divider network	Custom built		Not specified	
J	Go/no-go relay assembly	Custom built		Not specified	

resistance ratio is not within prescribed tolerance limits for each input pressure, the go/no-go relay assembly is energized by the error signal output of the dc amplifier. This yields either a no-go-hi or no-go-lo visual indication, and an electrical signal that stops the programmer until it is manually reset. *Test Requirement 4*—The programmer actuates the voltage-to-pressure generator to apply a ramp pressure signal to the transducer under test, connects the regulated power supply to the transducer potentiometer, and converts the dc amplifier to a differentiating amplifier. Any out-of-tolerance transducer resolution measurement or discontinuity of potentiometer motion will cause a large voltage to appear at the output of the dc amplifier because of the differentiating action. This energizes the go/no-go relay assembly to produce a no-go indication. The tolerance level is readily adjustable to any desired value by varying the amplifier *RC* time constant.

Extending the Tester

The flexibility of the voltage-to-pressure generator makes it possible for this tester to handle almost any type of pressure transducer. However, the plug-in reference-ratio and measured-ratio dividers would have to be changed for each new transducer. If transducers with ac pickoffs are to be tested, an adjustable regulated ac power supply is necessary to excite the divider units.

3—RELAY TESTER

What the Tester Must Do

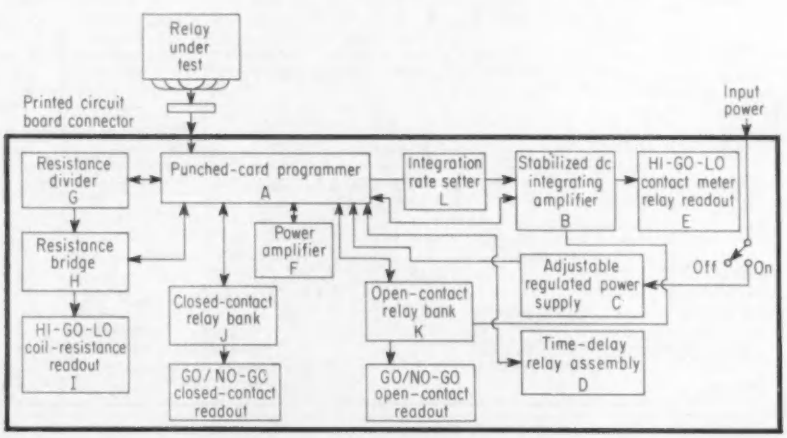
1. Verify that relay coil resistance is within prescribed limits.
2. Verify that a short circuit exists between normally-closed contacts.
3. Verify that an open circuit exists between normally-open contacts.
4. Verify that the relay energizes at a specified minimum coil voltage.
5. Verify that an open circuit exists between normally-closed contacts when relay is energized.
6. Verify that a short circuit exists between normally-open contacts when relay is energized.
7. Verify that relay deenergizes at a specified maximum coil voltage.
8. Verify that relay operating speed is within prescribed limits.

How the Tester Does It

General Circuit Operation—Printed circuit connector contains the proper header configurations and mounting holes for the types of relays that are to be tested. All printed circuit header terminals are connected to switches in the punched-card programmer. The programmer, in turn, establishes the proper connections for a particular test from information coded on the cards. The tester shown requires nine cards for each type relay to be tested. *Test Requirement 1*—The relay to be tested is inserted in a header and the first card placed in the programmer. The resistance divider (whose external resistance is determined by punched-card actuated relays that select the proper network of precision resistors) and the relay coil under test are connected into the resistance bridge. This network drives a sensitive polarized relay that gives a hi, go, or lo visual readout depending on the measured coil resistance. The hi-lo tolerance settings depend on test requirements and are adjusted beforehand with a self-check punched card. *Test Requirements 2, 3, 5, and 6*—The next card energizes or deenergizes the relay under test and connects either the normally-closed contacts or the normally-open contacts to the power supply and to the closed-contact relay bank or the open-contact relay bank. Closed contacts energize relays in the closed-contact relay bank, while open contacts deenergize relays in the open-contact relay bank. Where the contact resistance of a relay under test must be less than a specified amount, sensitive relays are used in the two relay banks. If the contact resistance is too high for the closed relay contacts under test, the closed-contact relay bank will not energize and there will be a no-go indication. In a similar manner, insufficient leakage resistance between open relay contacts under test will keep the open-contact relay bank from deenergizing and will give a no-go indication.

Test Requirements 4 and 7—The next card connects the power amplifier to the power supply and selects power amplifier gain. Depending on the test, amplifier output is the minimum voltage to energize the relay coil or the maximum to deenergize it.

Test Requirement 8—This time the punched card selects the proper integration rate setting for the integrating amplifier and the proper power amplifier gain, and starts the time-delay relay. After 1 sec, the latter connects a precise voltage to the integrating amplifier input and, at the same instant, turns on the power amplifier to energize the relay under test. When the relay closes, the input to the integrating amplifier is removed. The output of the integrating amplifier is proportional to relay pull-in or drop-out time, and must fall within the prescribed limits of the contact meter relay setting to yield a go indication. Too short or too long time will give a lo or hi indication.



Extending the Tester

Almost any type of relay can be tested if sufficient header configurations are included on the printed circuit board. Uncased relays without header connections can be handled by using flexible leads with alligator-type ends, if contact resistance is not too critical.

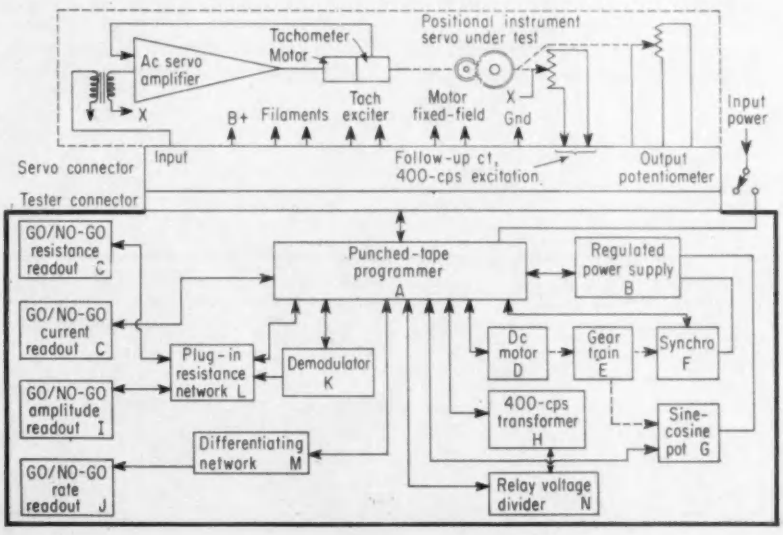
THE RELAY TEST-SYSTEM COMPONENTS

Item	Classification	Vendor	Part number	Approximate cost	Description
A	Punched-card programmer, including reader	Remington-Rand Div. of Sperry Rand Corp. New York, N. Y.	3906	$6,450 for one prototype	Uses standard 45-column Remington-Rand punched cards with capacity of 540 bits per card. Automatic feed magazine holds 625 cards. Top speed is 100 cards per min. Electric sensing switch box (RR #1800196) and connection box (RR#1700171) provide for electrical output from all 540 positions. Receiving magazine capacity is 850 cards. Current carrying capacity of switch box contacts is 1 amp maximum at 24 volts dc. Voltage ratings are for no current flowing at time contacts make and break.
B	Stabilized dc integrating amplifier	Electrol, Inc. Los Angeles, Calif.	Models 1-A and 1-C	$120 for both	To obtain a stable integrating dc amplifier, Model 1-A (see item B under pressure transducer tester) is used in conjunction with a Model 1-C chopper-stabilized amplifier. The latter has a conversion gain for dc-to-dc of 1,000 and an output voltage of ±10 volts.
C	Regulated power supply	Hewlett-Packard Co. Palo Alto, Calif.	Model 712 B	$365	See item B under amplifier tester.
D	Time-delay relay assembly	G-V Controls, Inc. East Orange, N. J.	HF-01	$19.90	Hot-wire time-delay relay with time adjustable from 0.5 to 1.25 sec. Nominal heater voltage is 28 volts dc.
E	Contact meter relay	Assembly Products Palm Springs, Calif.	Model 455-C	$50 to $125	See item D under amplifier tester.
F	Power amplifier	Krohn-Hite Instrument Co. Cambridge, Mass.	Model UF-101	$425	Delivers 50 watts of audio power. Frequency response is within ±0.5 db from 0.5 cps to 30 kc. Low frequency cutoff can be set as low as 0.03 cps. Output impedance taps of 2, 4, 8, 16, and 450 ohms are available.
G	Resistance divider	Custom built		Not specified	Plug-in multi-resistance network with resistance value determined by punched-card coding.
H	Resistance bridge	Custom built		Not specified	Precision resistor network connected to circuit under test and to resistance divider described above.
I	Coil resistance readout	Custom built		Not specified	These major assemblies consist of sensitive relays, with the operating coil voltage determined by the detailed tester mechanization. The characteristics of a typical relay are listed below.
J & K	Relay banks	Custom built		Not specified	
	Sensitive telephone-type relays	Potter & Brumfield, Inc. Princeton, Ind.	LTL Series	$20	Designed for sensitive dc operation. Fast acting with 50-milliwatt coil per pole; operating time of less than 10 millisec with greater coil power. Up to 24 contacts available per relay. Maximum noninductive contact rating is 4 amp.
L	Integration rate setter	Custom built		Not specified	Consists of several resistors. One end of each is connected to the integrating-amplifier input. Card programmer chooses resistor for a particular test to obtain proper integrating rate by varying integrator RC combination.

4—INSTRUMENT SERVO TESTER

What the Tester Must Do

1. Verify that the correct resistance exists between the connector pins and the ground with no power applied.
2. Verify that the proper plate- and filament-power-supply currents are being drawn with the servo input grounded.
3. Verify that the output signal amplitude is within prescribed limits with input carrier signal modulation frequencies of 0.1, 0.2, 0.5, 1.0, 5.0, 10.0, and 20.0 cps.
4. Verify that the output signal changes rapidly enough in response to a step input signal.
5. Verify that the output signal is within prescribed limits for input signal magnitudes of 0.1, 0.2, 0.5,



1.0, 2.0, 5.0, and 10.0 volts rms.

How the Tester Does It

Test Requirement 1—The punched-tape programmer selects the servo connector pins in turn, each time applying a test voltage from the regulated power supply. The plug-in resistance network is connected either in series or in parallel with the internal servo resistance, in the proper magnitude to normalize the current flow. The current drawn in each case is monitored by the go/no-go resistance readout, which consists of a sensitive relay combination. A go indication will result if the currents are within the specified limits, a no-go signal if they are too high or too low.

Test Requirement 2—This test is similar to the previous one except that the plate and filament currents are monitored by the go/no-go current readout. Again, this consists of a combination of sensitive relays.

Test Requirement 3—The programmer supplies the dc motor with a series of specified voltages that yield the proper shaft speed (and input signal frequency) after the gear-train reduction. The gear train drives a synchro and a sine-cosine pot, the first for ac servos and the second for dc. For the ac servo shown being tested, the synchro gives a constant peak-to-peak modulated 400-cps signal at a frequency dependent on motor speed. Servo output is fed through the demodulator and the plug-in resistance network. Again, the latter serves a normalizing function by keeping the specified peak-to-peak servo output to the go/no-go amplitude readout constant, even though servo response falls off as the input fre-

THE SERVO TEST-SYSTEM COMPONENTS

Item	Classification	Vendor	Part number	Approximate cost	Description
A	Punched paper tape programmer	California Technical Industries Belmont, Calif.	171	$1,800	Uses 1-in. eight-channel standard tape with holes on 0.1-in. centers. Programmer reads a 10-row frame at a time. Maximum rate for continuous operation is six frames per sec; 15 frames per sec is permissible for short periods. Contacts are rated at 50 milliamp. Has visual neon bulbs in 8x10 hole pattern for checking new tapes. Requires 375 watts of 115-volt, 60-cps power.
B	Regulated power supply	Hewlett-Packard Co. Palo Alto, Calif.	Model 712 B	$365	See Item B under amplifier tester.
C	Go/no-go resistance and current readouts	Assembly Products, Inc. Chagrin Falls, Ohio	VHS Relay	Dc $41.50 to $55.50 Ac $46.50 to $61.50 (Mil-spec adds 50%)	The very high sensitivity relay has a moving contact carried on a pivoted coil that takes a position relative to the applied current or voltage. Infinite variations are available from 0.2 microamp to 10 amp, and from 0.1 millivolt to 500 volts. Repeatability of better than 1 percent is specified. Several contact configurations are available. The one used here has a zero center and high and low normally-open contacts.
D	Dc motor	Globe Industries, Inc. Dayton, Ohio	Type MM	$40	Small, lightweight, permanent-magnet dc motor. Various armature windings are available for a wide range of speed and torque characteristics. Voltages range from 6 to 100 volts dc; no-load speeds from 6,000 to 22,800 rpm.
E	Gear train	Bowmar Instrument Corp. Fort Wayne, Ind.	750-GH	$250 to $450	Precision servo gear head with gear ratios up to 620:1 available in 0.75-in.-diam by 1-in. frame. Starting torque is less than 0.005 in.-oz and backlash is less than 30 min.
F	Synchro	Eclipse-Pioneer Div. Bendix Aviation Teterboro, N. J.	AY-500-3	$34.50	Miniature synchro control transformer. Nominal input voltage is 26 volts, 400 cps. Maximum line-to-line stator voltage is 11.8 volts. Maximum error spread is 30 min.
G	Sine-cosine potentiometer	Technology Instrument Corp. Acton, Mass.	RVP3-S-59	$70	Contains two wipers spaced 90 deg apart, yielding a sine-cosine output as shaft is rotated. Resistance elements are available from 300 to 200,000 ohms and power rating is 6 watts at 250 deg C. Standard linearity is ±0.1 percent.
H	Transformer	Numerous vendors		$25 to $50	
I & J	Latching relays for go/no-go readouts	Filtors, Inc. Port Washington, N. Y.	Type L26F18	$33.28	Magnetically-held electrically-reset six-pole double-throw hermetically-sealed subminiature latching relay. Normal dc coil voltage is 26.5 volts, with 200 ohms specified for latching coil and 375 ohms for reset coil. Contacts are rated 1.5 amp inductive or 3 amp resistive. Latch-in time is 10 millisec. Dry contacts are available and test results indicate 1 million operations without malfunction.
K	Demodulator	Industrial Control Co. Wyandanch, N. Y.	Model 707-A	$205	Extracts the modulated data from a suppressed-carrier-modulated 400-cps input. Input impedance is 1 megohm and the transfer gain is 1 volt dc per volt rms.
L	Plug-in resistance network	Custom built		Not specified	Items L and M are simple passive resistance and capacitance networks, while Item N consists of several programmer-operated conventional relays. These relays, together with a resistance network, divide the 400-cps transformer voltage in accordance with the programmed instructions.
M	Differentiating network	Custom built		Not specified	
N	Relay voltage divider	Custom built		Not specified	

quency increases. The go/no-go amplitude readout contains two biased sensitive latching relays that yield go or no-go indications, depending on whether the amplitude falls within limits.

Test Requirement 4—The programmer furnishes a step input to the servo from the 400-cps transformer. The rate of change of the output signal is determined by connecting the servo output potentiometer to the differentiating network. If the rate of change is above a predetermined value, the sensitive relay in the go/no-go rate readout will close, giving a go indication.

Test Requirement 5—The programmer controls the relay voltage divider (supplied from the 400-cps transformer) so that a sequence of specified steady-state input signals are fed to the servo. The servo follow-up output is demodulated and fed through the plug-in resistance network into the amplitude go/no-go readout. For this test the latching relays in the readout stay latched unless servo output drops below a specified value. A no-go indication results if a relay unlatches.

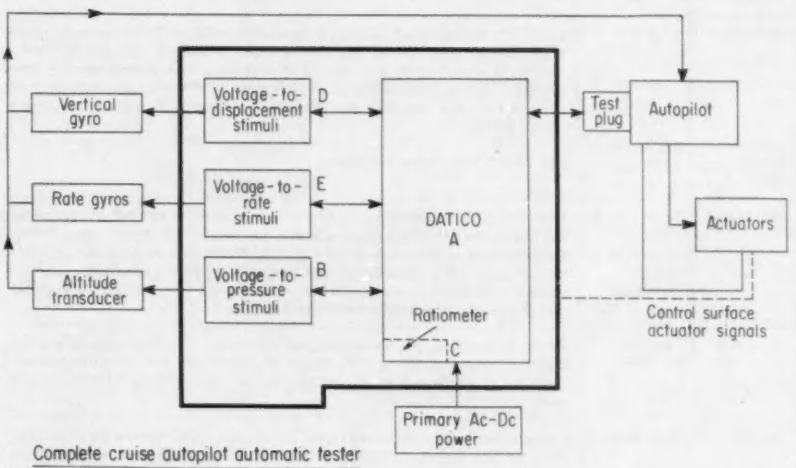
Extending the Tester

While this tester is flexible enough to automatically test a large variety of servos, it is primarily intended to verify instrument-servo performance where an electrical follow-up signal is available and no servo torque or shaft output load tests are required.

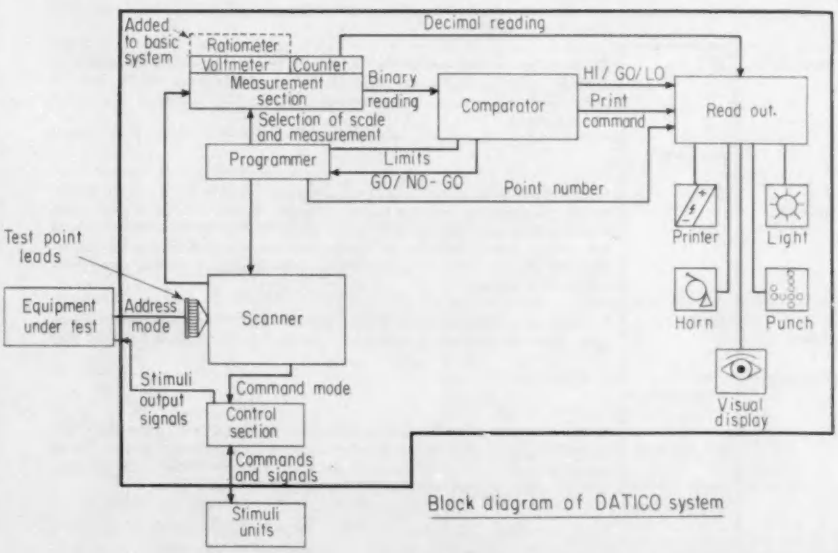
5—CRUISE AUTOPILOT TESTER

What the Tester Must Do

1. Verify that ac and dc line currents obey prescribed limits.
2. Verify that power supply voltages are within prescribed limits.
3. Verify that the ratio of control-surface output voltage to displacement-gyro voltage is within prescribed limits for both the pitch and roll channels.
4. Verify that the ratio of control-surface output voltage to rate-gyro voltage is within prescribed limits for both the pitch and yaw channels.
5. Verify that the control-surface output voltage overshoots within prescribed limits for a step input in output voltage from the roll-displacement gyro.
6. Verify that the control-surface output voltage is within prescribed limits for pitch-up and pitch-down commands.
7. Verify that the control-surface output voltage is within prescribed limits for roll-right and roll-left commands.
8. With a pressure altitude of 30,000 ft and the hold-altitude relay energized, verify that the control-surface output voltage is within prescribed limits when the pressure altitude is changed to 31,000 ft.
9. Verify that the control-surface output voltage is within prescribed limits when the pressure altitude is changed from 31,000 ft to 29,000 ft.
10. Verify that the control-surface output voltage is within prescribed limits when the hold-altitude command is removed.
11. Verify that the rate of change of the control-surface output voltage is within prescribed limits in response to step input voltages in the pitch, roll, and yaw test channels.



Complete cruise autopilot automatic tester



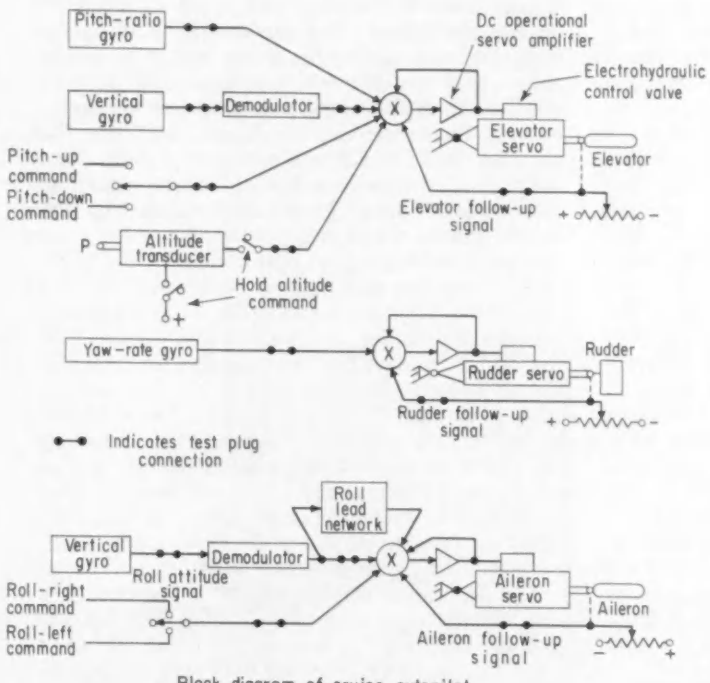
Block diagram of DATICO system

How the Tester Does It

The tape program is prepared in accordance with test requirements and includes specified tolerances on cur-

THE AUTOPILOT TEST-SYSTEM COMPONENTS

Item	Classification	Vendor	Part number	Approximate cost	Description
A	Universal automatic voltage, count and time measurement system	Northrop Aircraft, Inc. Anaheim, Calif.	DATICO Model M-1	$65,000	The standard DATICO (Digital Automatic Tape Intelligence Check-Out) unit will automatically check out any system for voltage, count, and time measurements (see accompanying block diagram). The major assemblies are the programmer, scanner, measurement section, comparator, and readout. The programmer uses an eight-bit-per-frame punched paper tape and a patchboard. The eight-bit information is multiplexed to give 80 bits per frame. The scanner is an electromechanical communicator that performs the functions of address and command. It selects the proper input and output leads of the system being tested, as well as controlling the required input signals. The measurement section consists of a digital VTVM and a frequency meter. Both visual and electrical outputs are provided. The comparator has memory, decision, and command capabilities and is entirely electromagnetic, making use of binary logic. Various readouts of test information are available; the standard is printed paper tape, but there are also visual displays and visual high or low indications. Go readings are printed in black along with the test number, and no-go readings are printed in red. The printed information is decimal. Both packaging and detailed design can be tailored for each testing application. For the auto-pilot test discussed here, a digital ratiometer must be included in the measurement section in addition to the VTVM.
B	Volts-to-pressure generator	Husan, Ltd. Santa Monica, Calif.	MK-1	$22,500	See Item C under transducer tester.
C	Digital ratiometer	Electro Instruments San Diego, Calif.	R105L	$2,250	The ratiometer is basically a null-seeking digital potentiometer that automatically balances by switching decades of precision resistors until a portion of the reference voltage equals the input voltage. Visual and electrical readouts are available. This model handles ratios of 0.00000 to 1.09999 with an accuracy of ±1 digit and a sensitivity of 1 millivolt. The average reading time is 1.5 sec and the nominal voltage range is 100 volts.
D	Voltage-to-displacement generator	Custom built		Not specified	Both of these items must be developed, but since absolute accuracy is not essential due to the ratio-type measurements used during the gyro tests, the two generators could be simple positional and velocity servos with electrical signal outputs. The input signals can be readily supplied from the DATICO programmer in the form of relay commands that apply fixed predetermined voltage inputs to the two servoamplifiers.
E	Voltage-to-rate generator	Custom built		Not specified	



Block diagram of cruise autopilot

rent, voltage, and voltage ratio readings, as well as the commands required to carry out the test program. The proper stimuli are commanded for each test sequence, and the autopilot current, voltage, or voltage ratio is measured by the DATICO measurement section and compared with the tolerances given on the tape. If the readings are within tolerance the test is continued; if out of tolerance, a no-go condition is indicated and the test sequence is stopped. As pointed out in the component listing, the stimuli sections for altitude and rate must be developed, since they are not included in the basic DATICO. However, they can be readily mechanized using positional and velocity servos. The use of ratio measurements simplifies the development of these stimuli —the absolute values of gyro attitudes and rates are not important. Although a detailed description of each test procedure is not included, most of these are self-evident from the accompanying diagrams.

Unity-Coupled Shear Orifice Yields Reliable Servovalves

A totally new approach to the design of electrohydraulic feedback amplifiers has produced a servovalve* with only two moving parts and with impressive advantages over conventionally designed valves in every area of interest to users. The new valve has:



- **inherent unity feedback of spool position, reducing sensitivity to load, pressure, temperature, and vibration**
- **high spool-centering forces and large clearance areas, permitting operation even with highly contaminated fluids.**
- **closed-center control ports, hence low quiescent leakage**
- **fewer parts, no springs, no clearances that require hand-adjusting**
- **balanced, symmetrical design, insensitive to temperature and pressure variations**
- **inherent dither, reacting directly on free-floating spool**
- **size, weight, and cost comparable to or better than conventional valves**

THOMAS J. THOMAS
Askania Kearfott Hydraulics

Eight out of ten of today's electrohydraulic servovalves use as a first stage the common flapper-nozzle control circuit of Figure 1. In this conventional arrangement, the two nozzles are connected to chambers at either side of a control piston, and the two chambers are connected to the high-pressure oil supply by way of small fixed orifices. Moving the flapper away from one of the nozzles causes the oil pressure to decrease in the chamber to which that nozzle is connected; at the same time the pressure in the other chamber increases because oil flow from its nozzle has been reduced. The piston must then move toward the lower-pressure chamber.

The piston will continue to move as long as the flapper is displaced, unless some counteracting force or feedback is applied. Conventionally, its differential force is balanced against a calibrated spring at either end; the design is open-loop and hence quite sensitive to load, temperature, and pressure variations. Other valve designs use feedback (mechanical or hydraulic) to reposition the flapper as the piston moves; usually by adding moving parts.

The principal difficulty with the conventional design is due to the very small clearances that are required between the flapper and the two nozzles if the oil flow with no input signal (quiescent flow) is to be as small as possible. This flow seriously affects the average output requirements of the high-pressure oil supply (i.e., pump capacity) and it is especially important in aircraft and missile applications that it be held to a minimum. Thus, while nozzle diameters may be 0.015 in. or so, clearance between the flapper and a nozzle when the flapper is fully displaced against the other nozzle is usually only 0.0006 to 0.001 in. Contaminating particles with any dimension larger than this value may lodge between the nozzle and the flapper, and cause the valve to "stick" or fail in a hard-over position.

The limited maximum flow in the flapper-nozzle circuit also results in low maximum forces on the control piston, which is generally part of the four-way pilot valve spool, so that contaminating particles entering the main control ports can block motion of the pilot spool, too. The small clearances between the flapper and nozzles also require that the flapper be carefully hand-adjusted mechanically during assembly and test to give the best null in valve output for zero input signal. The balanced springs used to make this adjustment (see Figure 1) can add some stiction, and hence hysteresis, to the valve's over-all characteristic, and can cause the null point to shift as temperature varies. In addition, centering springs on the pilot spool, when used, contribute hysteresis and null shift.

The jet-pipe principle (Figure 2) represents a very different approach to hydraulic valve control that has been used in industry for about 30 years.

* *Patent applied for*

Reliability of jet-pipe units has been phenomenal—some units have given satisfactory performance for years while buried in concrete. The principle has found little use in military applications, however, because of its naturally high quiescent flow (of practically no concern to industrial users). In electronic terms, the jet-pipe is analogous to a class-A, push-pull power amplifier—it has high zero-signal flow and low power-conversion efficiency. On the other hand, the flapper-nozzle is designed to operate as a class-B amplifier—zero-signal flow is nearly at cut-off and power efficiency is relatively high.

What was needed, obviously, was a valve that operated at cut-off with the reliability of the jet pipe. Design simplicity was important, for it could add significantly to reliability (jet-pipe valves often use complicated pivoted linkages and springs for force feedback, Figure 3). Finally, a new servo-valve was evolved that had fewer moving parts and operated at cutoff with near-jet-pipe reliabilities.

New hydraulic amplifier design

The first stage of this new valve is an electro-hydraulic amplifier unique in two respects:

1. It uses a sliding shear seal driven by the input torque motor to uncover the control orifices. These "shear orifices" normally operate near cutoff, but can be opened by the torque motor to their full diameter (0.015 in.) for chip clearance; thus they combine the low quiescent flow of the flapper-nozzle design with the protection against clogging of the jet pipe.
2. The controlling shear orifices are located directly on the moving part of the second stage, which is a conventional four-way spool-type valve; in this way they provide unity hydraulic feedback of spool position to the first stage.

Figure 4 illustrates the principle of the shear-seal control orifices. In the null position (as shown) both orifices are completely closed by the arms of the sliding fork. Quiescent flow at null can be made as small as desired by reducing the clearance between the bottom of the fork and the surface in which the orifices are drilled. Production models of the valve hold the quiescent flow to 0.15 gpm maximum at 3,000-psi supply pressure.

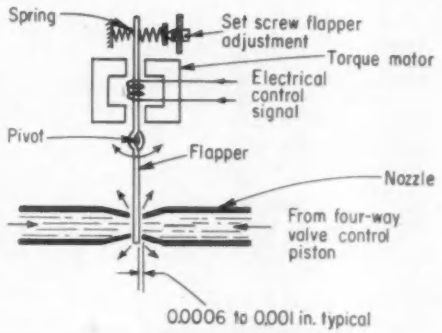


FIG. 1. Conventional flapper-nozzle amplifier has very small annular clearance dimensions even when fully open; requires careful hand-adjustment of flapper null position.

The sliding fork is part of the armature of a polarized dc torque motor. The armature is biased with a permanent magnet to a linear portion of its magnetization curve; this reduces signal distortion to a minimum. Opposite biasing by another permanent magnet, on the other side of the armature, results in a push-pull magnetic circuit with a maximum linear magnetization characteristic.

The polarizing fields are symmetrical and produce no net force on the armature. The plate currents from a push-pull dc amplifier pass through two field coils around the armature connected so that their fields cancel for zero signal input. Unbalancing of these two currents in one direction or the other by an input signal produces a net positive or negative magnetization of the armature and a turning torque against the torsion spring pivot. This kind of motor is needed, because the sliding fork must move linearly farther than the conventional flapper.

Note that the shear orifice hydraulic amplifier uses the same symmetrical hydraulic bridge circuit as the conventional flapper-nozzle system to actuate the second-stage spool. The major difference is that the shear orifice practically will not be clogged by

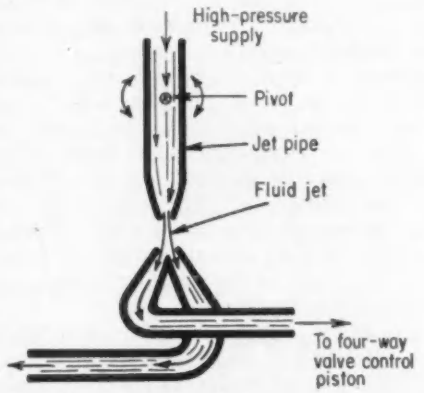


FIG. 2. Jet pipe is very reliable but has high quiescent flow. Receiving ports are often crossed as shown to simplify application of negative feedback.

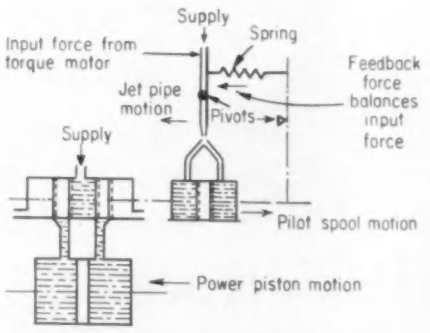


FIG. 3. One possible arrangement of jet-pipe amplifier driving a four-way spool valve shows how linkages, pivots, and springs have been used to apply force-feedback to the jet pipe.

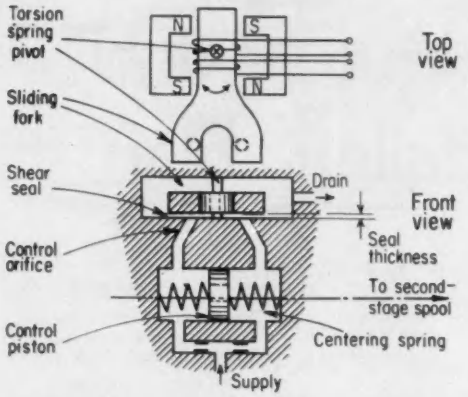


FIG. 4. Sliding fork driven by torque motor provides variable shear seal over two control orifices in a symmetrical hydraulic bridge circuit. Seal thickness can be reduced to make quiescent flow as small as desired. Shear orifice can be opened to full diameter for chip clearance.

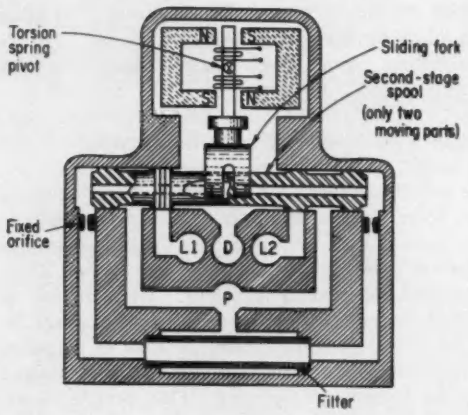


FIG. 5. Simplified section of new valve shows how shear orifices are located on four-way spool to achieve simple unity position feedback to first stage. Fixed upstream orifices are 0.0135 in. compared to 0.008 in. in conventional designs.

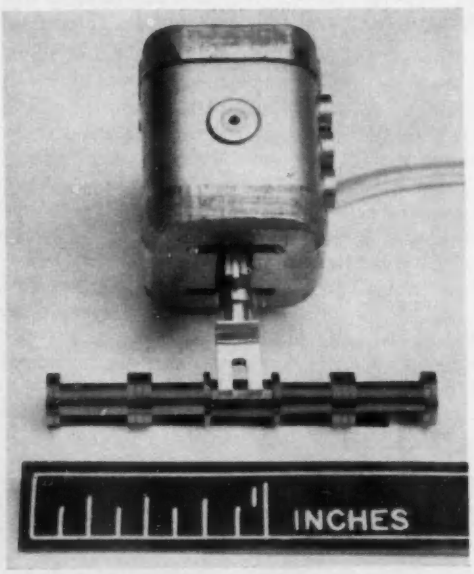


FIG. 6. Photograph shows the only two moving parts in the new servovalve—the torque motor's armature-fork and the four-way spool. Flatted area on spool provides shear seal for orifices under tines of fork.

the contaminating particles usually found in hydraulic systems. To see how the shear orifice clears itself, consider what could happen when the orifice is open only a very small amount in response to a small input signal. Under this condition, a very small chip can block it and compel the final actuator to make an incorrect motion. But then the primary feedback from the actuator to the input of the electronic amplifier will produce an error signal to open the shear orifice further and further until the chip clears. The maximum clearance dimension available with the shear orifice is the 0.015-in. diam of the orifice (maximum annular clearance in the flapper-nozzle circuit is about 0.001 in.).

The large control orifice openings possible with the shear seal also mean large differential forces for moving the four-way spool. The maximum differential force on a ¼-in. diam spool with a 3,000-psi supply is about 150 lb. Since particles caught between the sleeve and spool of the second stage of the valve have the same effect on the output actuator as ones caught in the shear orifice, the same electrical error signal occurs to open the shear orifice further and to increase the driving force on the spool until the stuck particle is sheared between the hardened edges of the spool and sleeve.

Notice that the shear orifice by itself does not eliminate the need for the centering springs against which the differential force on the second-stage spool is balanced (Figure 4). These springs can only be eliminated by applying position feedback from the spool to the fork. The problem is to do this without troublesome linkages and pivots.

Unity hydraulic feedback

Unity feedback of the position of the second-stage spool was brought about very simply, by locating the shear orifices directly on the spool itself. How this was done can be seen in the somewhat simplified sectional drawing of the entire valve in Figure 5. The torque motor circuit is shown schematically. The spool is drilled from either end to meet the two radially-drilled orifices. The surface of the spool on which the fork slides is flatted to get a good shear seal; this is visible in the photograph of Figure 6. The opposite side of the spool is also flatted, to eliminate warping.

Figure 5 shows that the spool will immediately follow up any motion of the sliding fork. If the fork is moved by the torque motor to uncover one of the shear orifices, a differential force will result across the spool in the right direction to move it back under the orifice. The spool must come to rest at the new position of the fork. The ratio of the differential force available to the inertia of the spool is very high, so the time lags in this sequence of events are extremely short. Figure 7 is the force-gain characteristic of the first-stage shear-orifice amplifier. Its slope is about four times that of the conventional flapper-nozzle amplifier. Figure 8 is

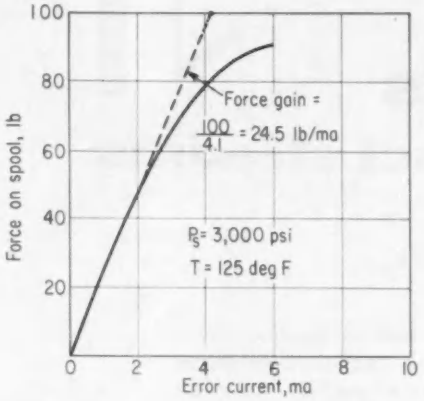


FIG. 7. Force-gain curve for shear orifice amplifier was made with spool blocked. Force on spool increases as position error between fork and spool increases. Force is shown here as function of instantaneous error current. Curve is the same at any position of spool.

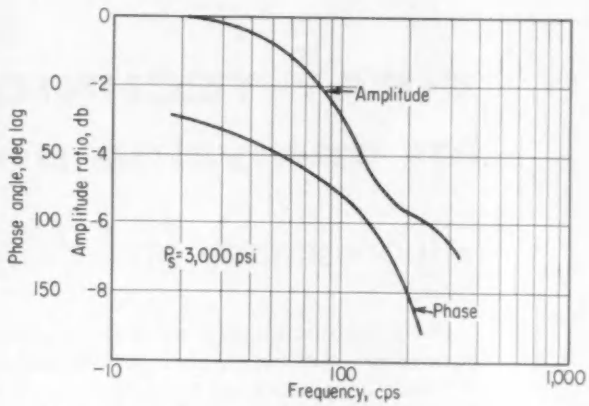


FIG. 8. Frequency response characteristics of shear-orifice servovalve rated at 2.7 gpm. Curves were made in standard manner as amplitude ratio and phase shift of unloaded Pegasus actuator driven by valve for constant current input.

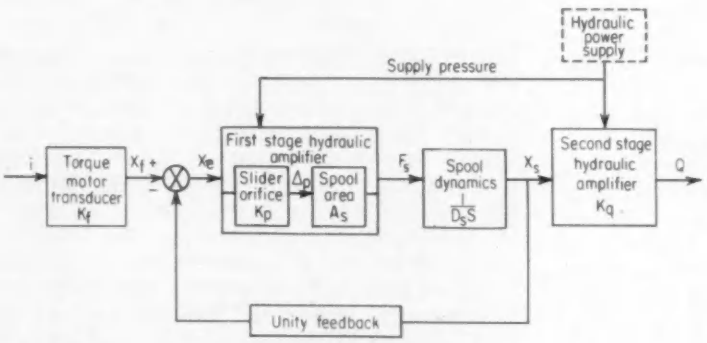


FIG. 9. Block diagram of shear orifice servovalve showing development of valve transfer function.

$$\frac{X_s}{X_f} = \frac{\frac{K_p A_s}{D_s S}}{1 + \frac{K_p A_s}{D_s S}} = \frac{1}{\left(\frac{D_s}{K_p A_s}\right) S + 1}$$

$$\frac{Q}{i} = \frac{K_f K_q}{\left(\frac{D_s}{K_p A_s}\right) S + 1} = \frac{K}{\tau S + 1}$$

Where:

K_f — Torque motor displacement, in. per ma
K_p — Slider-orifice pressure, psi per in.
A_s — Spool area, in.²
F_s — Spool driving force, lb
D_s — Spool damping, in.
S — Laplacian operator, sec^{-1}
X_s — Spool displacement, in.
X_f — Slider displacement, in.
X_e — Shear-orifice opening, in.
K_q — Second-stage flow, gpm per in.
K — Overall valve gain, gpm per ma
τ — Valve time constant, sec

the overall frequency response characteristic of the valve, including the lags of both the spool and the torque motor, as well as the unloaded Pegasus actuator whose amplitude ratio was measured for constant-current input to the torque motor.

Note that there are no springs, pivots, or linkages in this feedback scheme to contribute nonlinearity, hysteresis, or null shift. In fact, the entire valve has only two moving parts—the armature-fork and the four-way spool. The hydraulic feedback loop encompasses many disturbing signals not normally controlled by conventional force-feedback or pressure-feedback loops. Orifice coefficient variations due to silting, supply pressure and temperature variations, and external shocks and accelerations are all essentially nulled out in this positional feedback loop valve. The effects of flow-force reactions on the spool are similarly reduced.

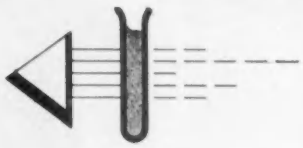
The driving amplifier can be somewhat simpler, since a dither signal need not be supplied. The free floating spool has an inherent dither at about 350 cps, which reduces errors due to static friction.

Development of transfer function

Figure 9 shows a block diagram of the new valve and indicates the development of its open-loop transfer function. The axial forces acting along a slide valve spool are generally random, for they are influenced by many uncontrollable factors, and pressure-flow relationships and flow-force reactions are nonlinear; but a hydrodynamically balanced spool design and the unity feedback reduce some of these effects. Even so, a linear analysis of this valve is still a compromise between theory and utility.

Tests of prototype valves indicate that a single-time-lag transfer function most nearly approximates the valve. The dominant time constant is that produced by fluid damping. The masses of the spool and fluid have little effect below about 500 cps.

Prototypes of this valve have had months of operational testing with no external filters or other fluid protection. No stoppages have resulted. Millions of cycles have also been run successfully without the internal filter. Similar-size orifices have operated dependably for years in jet-pipe valves.



X-RAY TECHNIQUES for analyzing product streams

•fluorescence and diffraction

The x-ray fluorescence analysis technique works best in analyzing the basic products of the metals industries and in detecting small concentrations of metals in products of the powder or fluid process industries. An x-ray fluorescence analyzer is now available that permits continuous on-line composition measurements. X-ray diffraction remains, for the time being, essentially a laboratory technique. But diffraction analyses can be used to set those environmental conditions that yield desired product composition.

PAUL S. GOODWIN, Applied Research Labs.

X-rays have been used for physical measurements since their discovery by Roentgen in 1895. However, it is only comparatively recently that they have been used to identify and quantitatively measure individual constituents of a compound. The acceptance of x-ray as an analytical technique came first with x-ray diffraction spectroscopy, and then with x-ray fluorescence. The parent phenomenon, x-ray absorption, predominates in such physical measurements as density, thickness, and level, but it is now gaining stature as an analytical method.

To be considered a truly analytical tool, an instrument should selectively measure one or more individual constituents of a substance in the presence of varying amounts of the remaining constituents. X-ray diffraction and x-ray fluorescence meet these qualifications, the first by distinguishing and measuring substances on the basis of crystalline structure, and the second by sensing atomic composition. Despite these seeming differences, both phenomena follow the same generalized fundamental laws. The difference between the techniques results from the ways these laws are applied.

X-ray diffraction

Selective reinforcement and cancelation of electromagnetic energy is employed analytically in the visible spectrum in the optical diffraction grating spectograph. Incident light to a ruled surface is broken up into component wavelengths with the intensity of each component bearing the same relationship to the others as in the original incident light. In a similar manner, any crystalline substance, Figure 1, exhibiting a regularity to the arrangement of its atoms will behave like the diffraction grating when the incident energy is in the x-ray region (0.01 to 100 angstroms) of the electromagnetic spectrum.

Selective reinforcement occurs when the radiating energy wavefronts from all excited elements are in phase. That is, each element's wavefront is some integral multiple of a full wavelength ahead or behind that of the parallel emerging wavefronts from other excited elements in the pattern. Similarly, selective cancelation occurs when the emerging wavefronts are out of phase. That is, the parallel fronts are some odd multiple of a half wavelength with respect to each other. The ability of such an array of atoms to produce selective reinforcement and cancelation depends on the specific wavelengths, angles, and spacing involved. In the x-ray spectrum, reinforcement occurs when Bragg's law (Equation 1) is satisfied:

$$n\lambda = 2\,d \sin\theta \qquad (1)$$

where n = some integer, λ = wavelength in angstrom units (A), and d and θ are defined as in Figure 1.

Since many types of d spacing are possible in crystals, there are likewise a variety of angles θ that will satisfy Bragg's law. During a scan through all possible angle θ's (without changing λ), a series of reinforcements and cancelations characteristically peculiar to the crystal being studied will result. An instrument that scans and detects the reinforcements is called an x-ray diffraction spectrometer. Once calibrated against patterns of pure standards, it identifies and measures the constituent parts of mixtures of crystalline substances. Such spectrometers have found many hundreds of applications in research and clinical laboratories; but as yet the physical problems of proper sample preparation, tedious and time consuming scans, and severely tight tolerances on the sample surface and crystal orientation have hampered the use of x-ray diffractometers as stream analyzers.

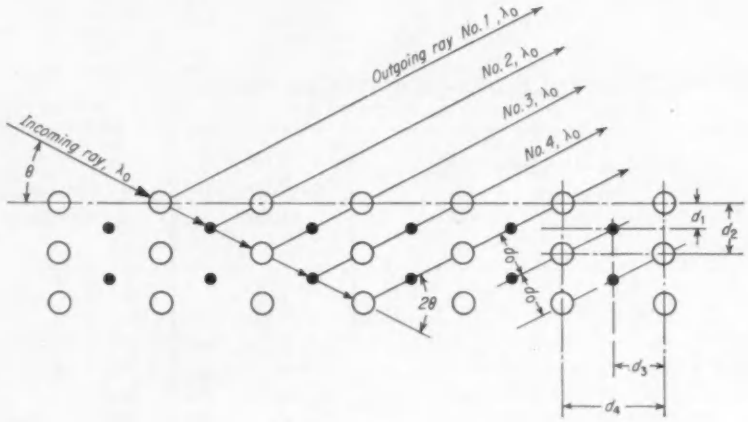


FIG. 1. When the incoming x-ray strikes a crystalline material oriented in accordance with Bragg's law the resulting outgoing rays are in phase and their intensities reinforce each other.

X-ray fluorescence

The phenomenon of fluorescence in the visible spectrum is worthy of review here since it is analogous to x-ray fluorescence. Photons of relatively high-energy radiation (ultraviolet) bombard the outer or valence shell electrons of a phosphor and knock one or more electrons out of orbital position. The phosphor then captures passing electrons to replace the lost ones. During replacement there is a change in the binding force on the electron, causing a release of energy. The released energy takes the form of visible light at the phosphor's characteristic wavelength. Since no process is 100 percent efficient, the incident energy must be higher-energy radiation than the released visible energy. This is the same as saying that the exciting energy must be a shorter wavelength than the emitted fluorescent energy.

A closely parallel situation exists in the x-ray region of the electromagnetic spectrum. The incident and emitted energies involved are much higher than visible energies, but bear the same relationship to each other. Incident x-radiation photons penetrate deep into the atom, Figure 2, and bombard the innermost electron shells. *K*, *L*, and *M* orbital electrons are ejected from the atom, raising the atom to a higher energy state. Electron replacement occurs from the more outlying shells—giving rise to fluorescent spectral lines in the x-ray region. As in visible fluorescence, the x-ray fluorescent wavelength is longer than the incident, or exciting, wavelength. Each element produces fluorescence at wavelengths peculiar to itself and at an intensity relative to the amount or number of the element's atoms present in the irradiated material.

X-ray fluorescence, therefore, can be used to determine the elemental or atomic composition of substances. Figure 2 depicts the bombardment of an iron atom with suitably hard (high-energy) x-ray photons. There is a certain probability that such a photon will collide with a *K*-orbit electron and eject it from the iron atom, leaving the atom with an unnatural charge distribution. Replacement of the ejected electron may come from the outer *L*, *M*, or *N* orbits, which in turn must replace the lost electron from either a more outlying shell or from a passing electron. Different fluorescent wavelengths are emitted by the iron atoms, depending upon the orbital jump involved, and these wavelengths are classified by the electron jump that produced them. For instance, the *Fe* $K\alpha$ jump produces a spectral line at 1.94 angstroms, while the *Fe* $K\beta$ jump produces a spectral line at 1.76A. (The $K\gamma$ jump does not actually occur in iron, but is shown for completeness in Figure 2.)

A vacated *L* or *M* orbit electron location, whether by loss to the *K* orbit or by original x-ray photon collision, gives rise to one of a multitude of possible *L* orbit spectral lines, as shown in the table (page 96 and Ref. 1), because of the increase in combinations of jumps associated with a shell of eight electrons in the *L* orbit compared with two in the *K* orbit. This is even more pronounced for *M* orbit spectral lines, where for iron up to 14 electrons can exist in slightly different states of energy. The significant factor in this process is that the fluorescent radiation becomes harder and harder (and correspondingly higher-energy radiation is required for excitation) as the jump phenomenon moves in

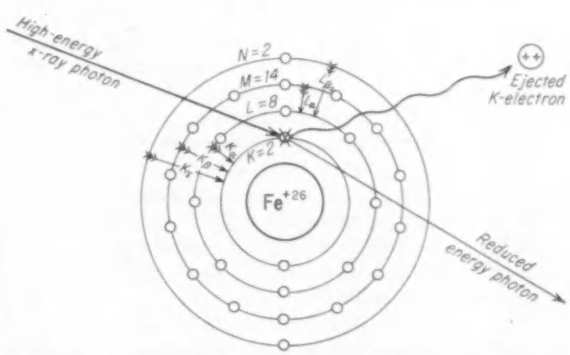


FIG. 2. X-ray bombardment of a typical (iron) atom causes ejection of one or more orbital electrons. The excited atom then replaces the lost electrons, releasing fluorescent x-radiation. The fluorescent energy has a wavelength peculiar only to the element and orbit involved.

X-RAY FLUORESCENCE DATA OF TYPICAL ELEMENTS

At. No.	Element	EMISSION WAVELENGTHS, angstroms					EXCITATION, kilovolts		ABSORPTION EDGES, angstroms	
		K Series		L Series						
		α	β	α	β	γ	K	L	K	L_I to L_{III}
20	Calcium	3.360	3.089	36.39	36.02	.....	4.038	0.40	3.070	31.07 – 35.83
24	Chromium	2.290	2.085	21.52	21.19	.....	5.988	0.68	2.070	16.7 – 20.7
25	Manganese	2.102	1.910	19.39	19.04	.....	6.542	0.76	1.896	
26	Iron	1.936	1.757	17.58	17.72	.....	7.113	0.85	1.743	Data not
27	Cobalt	1.789	1.621	15.94	15.62	.....	7.713	0.93	1.608	available
28	Nickel	1.658	1.500	14.53	14.24	.....	8.337	1.02	1.488	
47	Silver	0.560	0.497	4.15	3.93	3.51	25.53	3.83	0.486	3.24 – 3.67
50	Tin	0.491	0.435	3.600	3.385	3.001	29.18	4.45	0.425	2.79 – 3.17
74	Tungsten	0.210	0.184	1.476	1.282	1.098	69.51	12.09	0.178	1.02 – 1.22
78	Platinum	0.187	0.164	1.313	1.120	0.958	78.35	13.86	0.158	0.894 – 1.07
82	Lead	0.165	0.146	1.175	0.982	0.840	87.95	15.86	0.141	0.782 – 0.951

toward the nucleus of the atom. This is because the K electrons are very tightly bound to the nucleus, and electrons moving inward to replace those ejected must give up more energy to achieve orbital balance than they would in moving from the M to L orbit, and so forth.

The table shows that each element produces a variety of simultaneous fluorescent spectral lines when subjected to continuous high-energy radiation. These fluorescent wavelengths do not overlap except in relatively few cases. Though it is not so stated in the table, the normalized intensities of all spectral lines produced by a single element bear a constant relationship to each other, regardless of whether the element appears alone or is mixed with others in the irradiated sample. Except for rare cases where interference or selective absorption is present, the measurement of but one of the available spectral lines of an element is sufficient to determine the element's concentration in the sample —once the conditions of the measurement are known and related to measurements made on standard materials. It is also possible to make simultaneous measurements at different wavelengths—one for each element—for multi-element analyses.

X-ray fluorescence analyses occasionally need to be corrected for absorption effect because of, for instance, the presence of extraneous elements in the sample. This is especially true if the extraneous elements vary in concentration. Fortunately, it has been discovered that an internal standard or reference wavelength obtained from sample or product can be used to effectively cancel the absorption effect. This discovery enabled the development of a practical process control x-ray fluorescence analyzer.

Figure 3 shows how the mass absorption coefficients of three typical elements change with the wavelength of the penetrating x-radiation. The general trend of each element is toward increasing absorption with longer and longer wavelength radiation, since the weaker the energy of the incoming photon, Figure 2, the more apt it is to be absorbed or highly scattered by the more numerous middle and outer orbital electrons. The numerical value of the absorption coefficient and the amount of the material present in the sample is important. Both values appear as exponents in the logarithmic equation that gives the effective transmission of the sample:

$$\frac{I_x}{I_o} = e^{-\mu x} \qquad (2)$$

where $\mu = \left.\frac{\mu}{\rho}\right]_\lambda \rho$

ρ = the density of the material
x = thickness of the material, cm

$\left.\frac{\mu}{\rho}\right]_\lambda$ = numerical normalized mass absorption coefficient at the wavelength λ in use.

The magnitude of the exponent μx determines the amount of correction necessary. For $\mu x < 1.0$, no correction is generally necessary. For $1.0 < \mu x < 10$, the correction can be very important. For $\mu x > 10$, correction is rarely practical. While not too precise, these numbers indicate how rapidly the upward sweep of the coefficients of Figure 3 can influence an x-ray spectographic analysis.

The discontinuities for elements in the absorption plot of Figure 3 bear an interesting relationship to the phenomenon of x-ray fluorescence. Immedi-

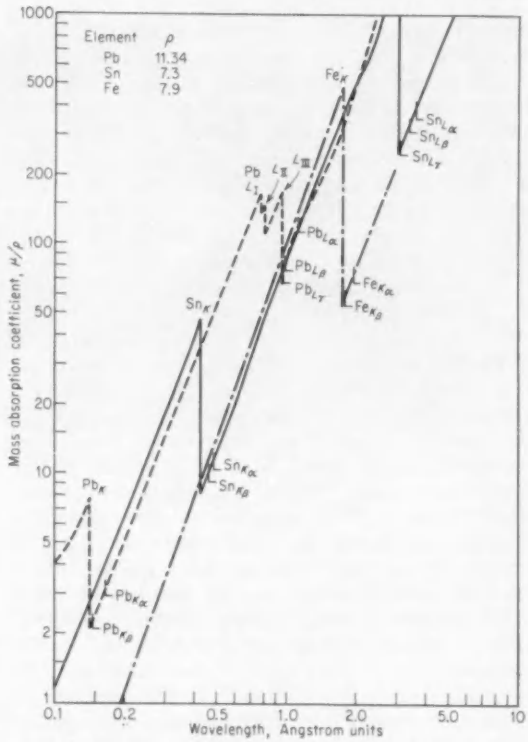


FIG. 3. Mass absorption coefficients for lead, tin, and iron at various wavelengths. Subscripts denote orbital change or absorption edge involved. Greek subscripts denote fluorescent lines produced. Density, ρ, values are for the elements in their metallic state.

ately to the right of each discontinuity appear the spectral lines of that element. The discontinuity nearest the *K* spectral lines is known as the *K* absorption edge of the element; the edges nearest the *L* spectral lines are similarly denoted as L_{I}, L_{II}, and L_{III} absorption edges. The region of high absorption to the left of the edge is responsible for the generation of the fluorescent spectral lines to the right of the edge. The more the region to the left of the edge that is excited by the incident radiation, the greater will be the intensity of the resulting fluorescent spectral line.

However, an element's excitation with incident x-rays of longer wavelength than the element's absorption edge will not produce fluorescence related to that edge. There is, therefore, a certain minimum energy (usually expressed in kilovolts rather than wavelengths) required to excite fluorescence in each of the orbits of each element. The minimum energies for *K* and *L* orbit spectra are listed for some elements in the table. In a practical situation, these minimum potentials should be exceeded, by at least a factor of two, to maximize the generation of fluorescence within the atom, and for this reason x-ray fluorescence analyzers tend to run at slightly higher power and require slightly more protective shielding than a corresponding x-ray total-thickness or density gage.

The scanning diffractometer

The basic elements of a scanning diffractometer usually take the form shown in Figure 4. The incident energy from an x-ray tube is made suitably monochromatic (single wavelength) by filtering the beam so that only the *K* radiation from the x-ray target impinges on the sample. Monochromatic energy eliminates spurious responses and provides sharp resolution. In the usual instrument, the x-ray tube, filter, and primary collimator are fixed. The sample is rotated about its axis at one angular speed and the secondary collimator and detector rotates about the sample at twice the sample's angular speed. In this manner, each Bragg angle is taken in turn and its intensity measured by the detector. Recording equipment connected to the detector writes the sample's entire diffraction pattern, which is then compared with those in a library of standard patterns to identify the unknown sample.

Applying such an instrument to continuous stream analysis raises severe engineering problems when the product under analysis is a solid. Continuous diffraction instrumentation is more readily applicable to powder streams where the randomness of the crystalline orientation of the powder particles generates all possible θ angles simultaneously. Because of this randomness, there is always a sufficient number of particles oriented properly to satisfy Bragg's law, Equation 1, which in turn creates a diffraction peak. When a single diffraction peak suffices for the powder stream analysis, the spectrometer of Figure 4 is operated at only one set of θ and 2θ angles, and the flow of powder in the stream is on a belt traveling normal to the plane of the figure.

When more than one diffraction peak is required for a complete analysis of the product, at least two spectrometer arrangements are possible:

1. A coarse primary collimator can be used as in Figure 4, and several short collimators and detectors

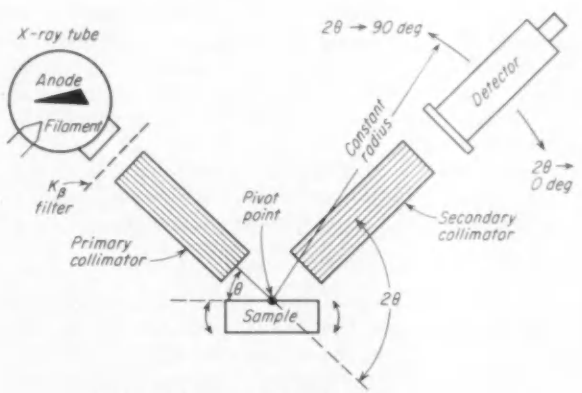


FIG. 4. The x-ray scanning diffractometer.

employed, one for each 2θ angle of interest. However, space considerations usually preclude such an arrangement except in rare cases.

2. A parafocusing spectrometer can be employed using a curved powder surface and focusing slits similar to the fluorescence analyzer of Figure 5B, but with the powder stream replacing the "fixed curved crystal" and the natural focus of the x-ray

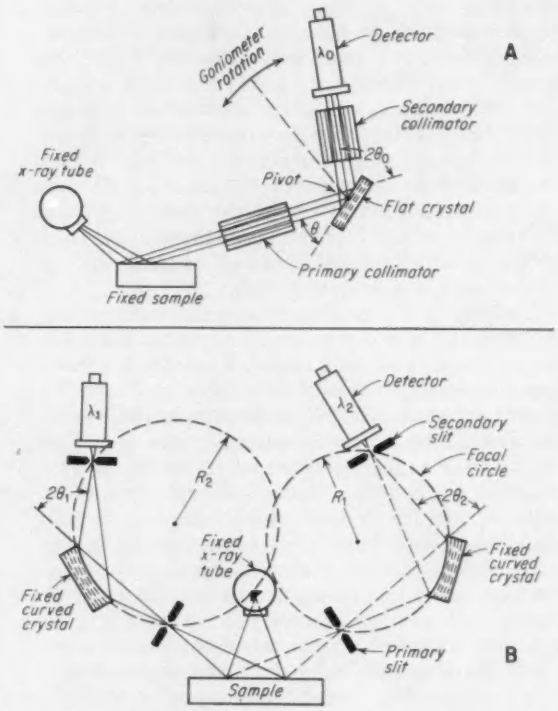


FIG. 5. X-ray fluorescence analyzers. In A the analyzer uses flat crystals to obtain monochromatic x-ray energy. The goniometer is rotated to pick up various wavelengths. In B the analyzer uses curved crystals. Here one optical system picks up the wavelength of interest and the other serves as a reference source. Both configurations must satisfy Bragg's law.

tube target replacing the primary slit system. In this type spectrometer, several secondary split-detector combinations can be arranged around the focal circle for simultaneous measurement of several diffraction peaks.

Instruments such as these have been proposed for process control applications, but as yet have not been placed into commercial production.

The x-ray fluorescence analyzer

Two arrangements of typical x-ray fluorescence spectrometers are shown in Figures 5A and 5B. In this class of equipment, a sample representative of the product is irradiated with x-rays whose energy exceeds the excitation potential of the desired elements in the product. The selected spectral energy is separated from the total energy by a diffraction crystal monochromator oriented in such a way that Bragg's law is satisfied for only the desired wavelength—namely, that of the element under investigation. The angles θ and 2θ are thereby set. The d spacing is likewise set by the crystal. After this, only ambiguous integral multiples of λ can satisfy Equation 1, and such ambiguity is avoided by choosing one of the K or L spectral lines for which there is no interfering radiation from the other elements in the sample.

In this manner, only the radiation characteristic of the element under analysis reaches the detector, and its intensity is linearly related to concentration when the sample is free of absorption effect. When absorption is present, the relationship may show curvature, which then has to be corrected in the final analysis. In a single-channel fluorescence analyzer, Figure 5A, this correction is done manually. In the multichannel analyzer, Figure 5B, the correction for absorption can be accomplished automatically and simultaneously by ratioing the analytical-channel signal to the internal standard signal. Such correction became possible with the recent discovery (Ref. 2) that certain wavelengths of scattered (nonspectral) radiation from the sample will respond to absorption and/or physical changes in the total sample in the same manner as the analytical channel, and yet are independent of changes in the latter's concentration. Ratioing the intensity of these two signals simultaneously provides correction for any absorption effects and eliminates error due to the environment or physical changes in the sample.

A practical x-ray fluorescence stream analyzer, the Quantrol (Applied Research Labs., Glendale, Calif.), Figures 5B and 6, uses the internal standard concept to advantage. The Quantrol consists of a spectrometer, a high-voltage supply for the x-ray tube, and an electronics console containing ratioing and calibration circuits. The spectrometer contains two curved crystal monochromators, one for analysis and the other for a compensating reference. The proper wavelengths and calibration parameters for each of these are chosen after laboratory tests have been made on samples from the actual production process.

Applications of x-ray fluorescence

The x-ray fluorescent analyzer has a fairly wide range of applications, covering the 80 percent of the elements in the periodic table above atomic number 19. The measurements of tin and zinc plating weights have been completely developed, and efforts are now under way to tie in such readings to fully-closed loop control.

Other applications of the analyzer include the measurement of various elements in ore concentrates or tailings in smelting operations and the measure-

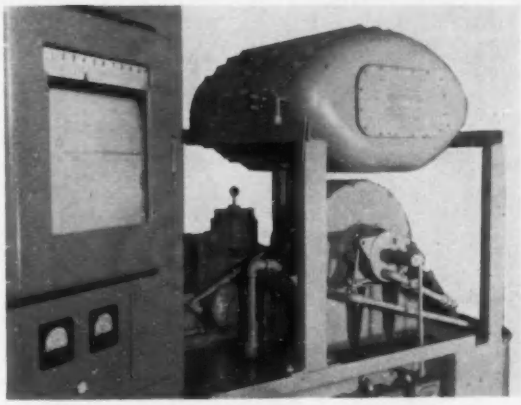


FIG. 6. The Quantrol x-ray fluorescent analyzer.

ment of copper and bromine concentrations in solutions.

X-ray emission fluorescence has been used in the petroleum industry for detecting the presence of metals in oil products, although this has been done on a laboratory basis. These specific applications have been reported (Ref. 3): control of additives blending with lubricating oils by analyzing for barium, calcium, and zinc; and analysis of bromine and lead in gasoline.

It is true that the x-ray fluorescence technique excludes such commercially important elements as hydrogen, carbon, nitrogen, oxygen, sodium, magnesium, and aluminum. The insensitivity of the analyzer to these elements in rows 1, 2, and 3 in the periodic table results from the fact that their emitted radiation is absorbed by air before the radiation reaches the Geiger counter. (On the other hand, measurement in a vacuum or helium atmosphere surrounding the sample can increase the signal and make analysis of many row 3 elements possible.)

Elements suitable for measurement by x-ray fluorescence can be in such product forms as liquids, slurries, powders, and solids. Measurements can be made "on the fly" and without contact, thereby eliminating scratching, marring, or otherwise destroying the surface. But measurements do not respond to process changes of less than one or two seconds duration, because the signal is lost in the inherent noise level.

The analysis obtained with x-ray fluorescence is more or less that of the surface which, therefore, must be characteristic of the product. For the usual solid, the effective depth of analysis is between 100 microns and several thousand microns. Such depths are suitable for gaging tin coating thickness on steel plate, one of the most highly developed applications of x-ray fluorescence measurements. Tin plate is sold on the basis of weight of tin per unit area of steel, but since the tin is all at the surface, where fluorescence is effective, the product analysis is essentially a measurement of thickness of the tin.

One method for measuring tin combines absorption and fluorescence. A primary beam (20 kv) penetrates through the tin and hits the surface of the iron. The iron then fluoresces and acts as a source of secondary x-rays at 1.94 A. The absorption of the primary and secondary x-ray beams is a measurement of tin thickness, and therefore the thicker the coating the lower the signal.

A more direct approach is that of measuring x-ray emission fluorescence of the tin itself, which measurement is independent of base-metal composition, tin purity, and alloy interface formation. Furthermore, Geiger counter current output increases with increased tin thickness, and such larger current provides increased accuracy when needed most—on coatings using a large amount of expensive tin.

In those applications where the characteristic surface is a heterogeneous combination of several elements, the depth of x-radiation penetration need be as little as only several hundred microns. The resulting emitted fluorescent signals are proportional to the amount of their respective elements present in the irradiated area. When the individual signals are normalized to a signal representative of the total intensity from the irradiated area, the individual constituents can be expressed directly as percent concentration. Multichannel x-ray fluorescence, therefore, permits accurate concentration measurements to be made when the irradiated area is changing due to motion of the product during its manufacture. Without such compensation for motion of the product, process measurements by x-ray fluorescence would not be practical.

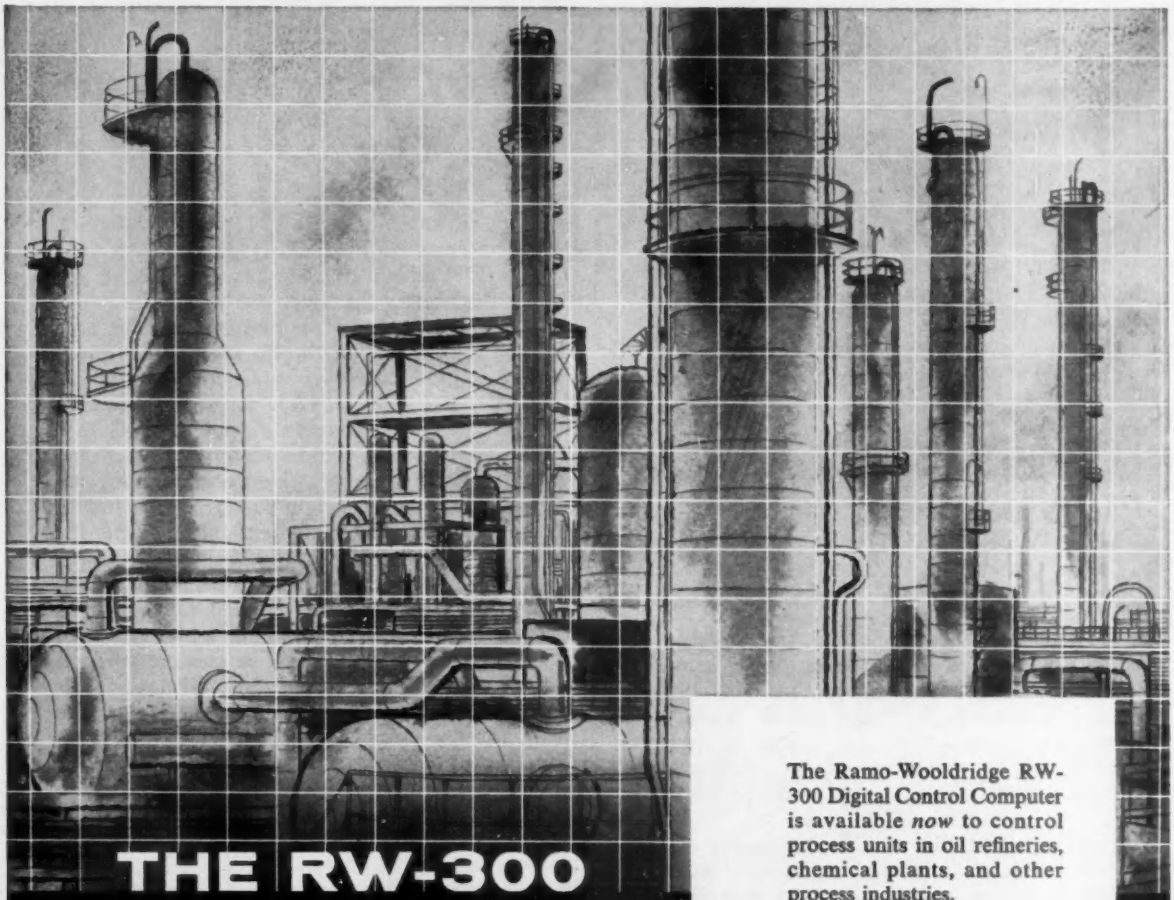
Continuous chemical control of a process by x-rays is now possible. Equipment is now commercially available using x-ray fluorescence, and instruments employing x-ray diffraction and x-ray absorption are under development. These instruments will perform analyses on materials that cannot be readily measured by other types of analytical equipment. Because of this, x-ray instrumentation is expected to supplement rather than obsolete such process equipment as mass spectrometers, and infrared and ultraviolet analyzers.

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For technical information on automatic process control and advanced data logging with the RW-300, write: Director of Marketing, The Thompson-Ramo-Wooldridge Products Company, P.O. Box 45067, Airport Station, Los Angeles 45, California, or call OSborne 5-4601.

THE THOMPSON-RAMO-WOOLDRIDGE PRODUCTS COMPANY

MICRO SWITCH Precision Switches

NEW



Actual Size

We've Miniaturized the Subminiature!

WEIGHT: *1 gram . . . 28 switches to the ounce . . . over 430 to the pound.* **SIZE:** *.500" long, .200" wide, .350" high.*
CUBIC CONTENT: *.035 cubic inches.* **ELECTRICAL RATING:** *5 amps-250 vac, 30 vdc. SPDT.*

After a long period of laboratory development, MICRO SWITCH announces this new, highly miniaturized precision snap-action switch and a complementary line of actuators.

We call it the "Sub-subminiature!"

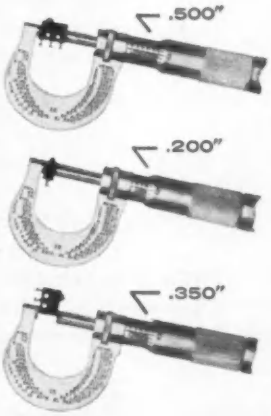
This new "SX" basic switch represents an entirely new set of answers to the space-weight problems in dependable precision switching. It combines new small size with more than ample capacity for wide usefulness, meeting the pressing demand for miniaturization combined with reliability.

In its exacting development, many problems of design, testing and quality control presented themselves. However, 23 years of experience proved of immense value. As a result, a new standard has thus been set by which all precision switches must be measured.

This broad experience can prove of equal value to you. Send for more information about this new switch. Request Data Sheet No. 148.

—•—

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.....combining the finest standard laboratory instruments with custom-designed assemblies for your *specific application.*

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for . . .

- programmed testing of electronic equipment
- multi-step process analysis and control
- go/no-go testing and measurement
- digital comparison and classification
- statistical analysis of equipment performance.



Dymec DY-5158 Automatic Subcarrier Oscillator Test Set

● Data-Logging Systems

Multiple inputs: Flow rates, rpm, pressures, temperatures, voltages.

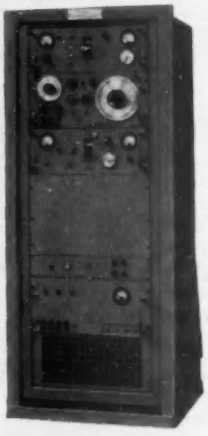
Outputs: Visual digital displays, punched tape, punched cards, graphic and printed records, computer data.



Dymec DY-5150 Data Scanning/Recording System

● Radar Simulator Systems

Used primarily for dynamic testing of radar systems, these versatile signal-generator/modulator assemblies simulate to a high degree of accuracy the numerous types and combinations of modulated signals produced by moving radar targets. Flexibility and high-performance are achieved through use of traveling wave tubes employing advanced modulation techniques.



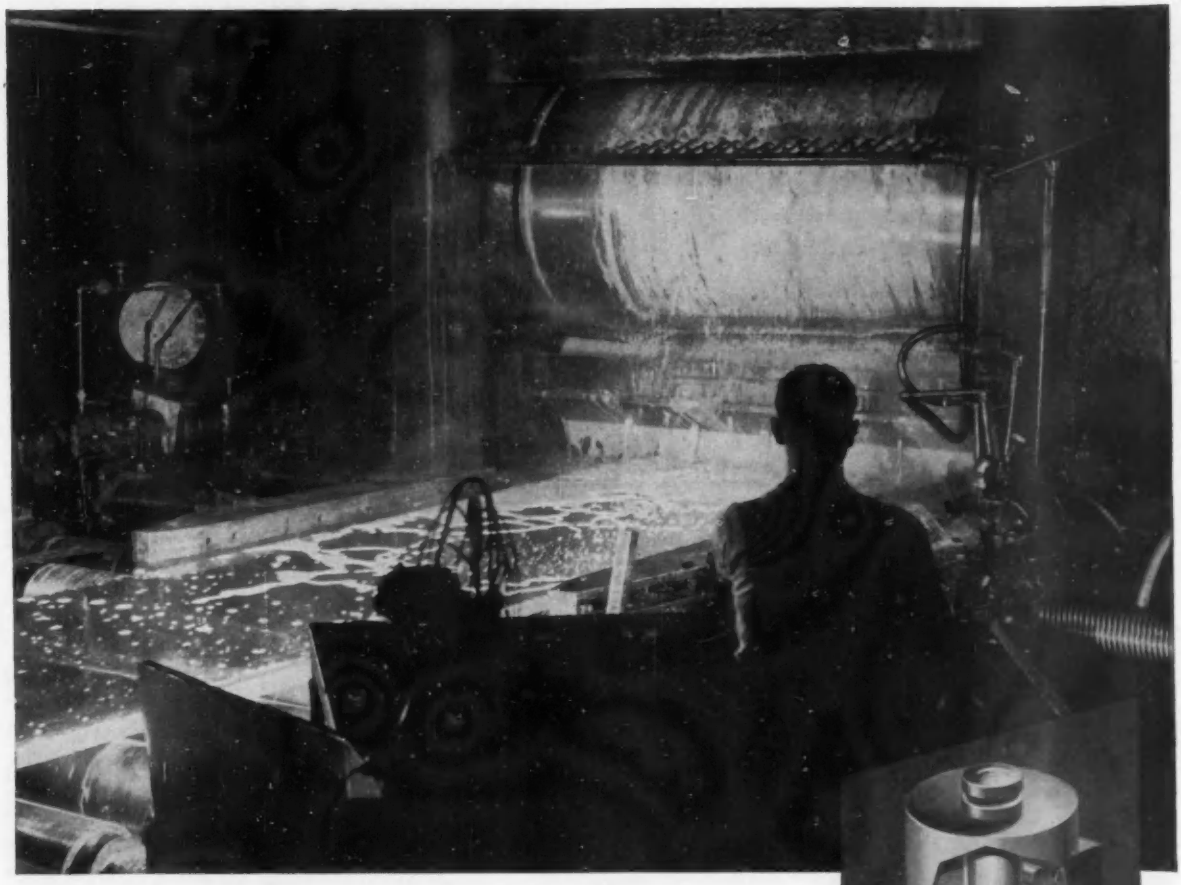
Dymec DY-5017 Radar Signal Simulator

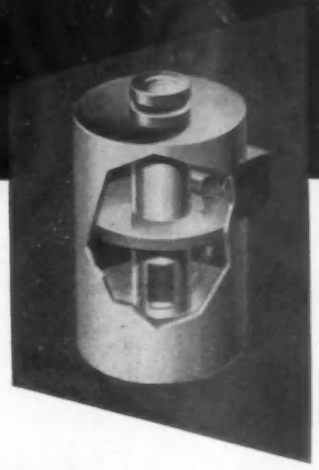
Investigate the technical and economical advantages of DYMEC Custom Instrumentation Systems for your particular operation. Write for technical data and name of your nearest DYMEC engineering representative. DYMEC technical representatives are at your service in 35 sales offices throughout the United States and Canada.

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Despite the tremendous forces unleashed in a rolling mill operation, the actual pressure exerted by the giant rollers can be measured with high precision by built-in B-L-H SR-4® Load Cells. These electronic transducers give the operator exact load readings, enabling him to roll sheets to just the proper thickness every time.

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SR-4® Load Cells have capacities ranging from 50 to 200,000 lb. Loads on the cells are converted to proportional voltage—permit the instruments for reading or recording changes to be located at any remote point.

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SR-4® strain gages • Transducers • Testing machines

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"We insist on the Philbrick amplifier for our new package," says Philbrick

HERE'S PHILBRICK ON PHILBRICK

"We use only the finest components in our products. That's why we insisted on Philbrick's new USA-3 Operational Amplifier as a sub-assembly for our new Analog Package, the UPA-2. We have found it (the USA-3) nifty and thrifty. We recommend it without reservation. And that goes for the UPA-2 — too."

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Discarded Welder Controls Creep Test Heating

Starting from scrap, Douglas engineers assembled a closed-loop system to control rapid, high-temperature heating.

L. W. McMAHON,
Douglas Aircraft Co.

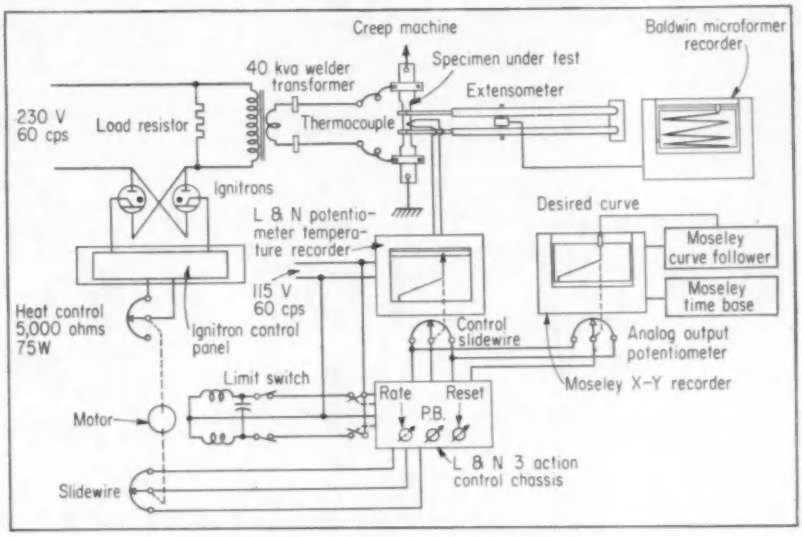


FIG. 1. Block diagram of heating control loop.

Douglas missile designers had a problem: find out how much the metals going into missile parts would "stretch" under flight conditions. The stretching of metals under high stress and temperature is called "creep" by airframe designers, who use creep data to design parts which must last for thousands of hours. Missile parts are different—they're designed for short-time use, and Douglas engineers had no short-time creep data available.

Testing Div. engineers came to the rescue: they salvaged an old resistance welder and modified it to control the heating of test specimens. The results were better than expected. The system controlled heating rates up to 1,600 deg F per sec, depending on specimen size and material, and worked best on 1- to 2-min tests in the 1,600-2,000 deg F range.

Figure 1 shows a diagram of the system. Engineers established no preliminary design specifications since they were using such scrap box items as the 40-kva transformer and the ignitron control panel from the welder. They did not attempt to fully specify such performance requirements as control point stability, control system response, or heating rate; instead they worked to make their pile of hardware into an efficient control system.

The engineers wired the thyratron control panel for manual and external rheostat control. They removed miscellaneous sections, such as weld timing circuits, but retained protective circuits such as ignitron cooling water temperature, warm-up delay, and interlocks. They used the welder's ignitron control panel and 40-kva transformer intact. The resulting circuit employs two GL-502A leading and trailing control tubes, two FG-95 leading and trailing firing tubes, and two FG-235A water-cooled ignitrons.

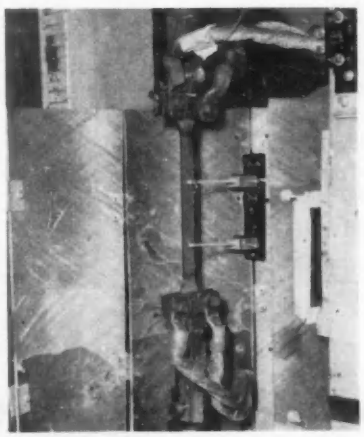


FIG. 2. Close-up of specimen mounted in tester; extensometer levers, thermocouple, and transformer output cables are connected.

The ignitrons are wired in a conventional back-to-back circuit in series with the transformer primary, and are controlled by varying the firing time vs. phase of the ignitron and control tube circuit. A simple variable RC phase-shift network in the grid circuit of the thyratron's control tubes provides continuous ignitron and transformer control from about 10 percent to 100 percent of full-load conditions. Transformer input currents from a 230-volt line range from 35 to 175 amp, with secondary currents from the 4-volt output ranging to a maximum of 8,000 amp.

A 40-amp dummy load connected in parallel with the transformer primary proved necessary when operating the ignitrons at low output to stabilize firing and regulation. Two 15-ft 500 MCM arc welding cables carry the transformer output current; short flexible jumper leads and simple clamp assemblies connect with the specimen (see Figure 2).

The temperature-control portion



When the target is space and a million dollars' worth of missile rests idly on the ground—not even a long countdown helps. In a showdown situation, the successful shoot depends on the "go, no-go" type of test that pinpoints the trouble.

NEXT TIME...LOOK TO INET FOR PRECISE GROUND POWER



This INET 400-cycle ground power unit was tailor-made for the Atlas. In meeting all of Convair's specifications for pre-flight calibration of electrical systems, the unit operates in parallel with the missile's power system and provides remote control regulation. Frequency regulation is ±0.2%. With shock load equal to a third of rated output, frequency recovers to ±0.2% in 0.15 seconds. Voltage regulation is ±0.5% with recovery time at 0.30 seconds.



Missile men desiring a special reprint of the above cartoon should write to "Count-down", c/o Inet Division of Leach.

INET DIVISION LEACH CORPORATION

18435 SUSANA ROAD, COMPTON, CALIFORNIA

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of the system is conventional: it consists of the primary measuring element, a thermocouple; the monitoring device, a recorder; and a control unit which supplies position-command signals to the motor-driven heat-source control.

A rather unique system supplies continuously variable control-point information: a Moseley X-Y plotter, with a curve-follower and a time-base attachment added, furnishes a slide wire indication of desired temperatures vs. time. In the curve follower setup, the plotter's Y-axis input is supplemented by a 175-kc oscillator, detector, and pickup, which senses the position of a predrawn metallic trace inscribed on the graph paper. The X-axis or drum is moved at a rate determined by the Moseley time-base generator. The curve follower (external analog) slidewire output varies as a function of the preplotted trace position vs. time. The slidewire, a three-turn Helipot, is wired in parallel with the control slidewire in the recorder to furnish control point information to the control unit.

This unit, a Leeds & Northrup three-action position-adjusting type, functions with a motor-driven unit to position the ignitron heat-control rheostat for the desired specimen temperature. Signals from the recorder and the curve follower are combined with those from the drive-mechanism slidewire in the input circuitry of the L&N controller. The front panel controls rate, proportional band, and reset actions; the adjusted error signal is fed to the L&N amplifier, whose output relays control power to the servo drive-motor. This in turn positions the ignitron control rheostat, a 5,000-ohm standard 75-watt Ohmite potentiometer.

The servo drive-motor, a two-phase Brown 77311-1 gear-head type, has an output shaft speed of 180 rpm. To provide adequate torque and to increase the life of the potentiometer, spur gears reduce this output to 30 rpm. Limit switches operated by a lobe on the spur gear limit the shaft rotation to about 270 deg, the full rotation of the rheostat. The drive mechanism or follow-up slidewire consists of a 1,000-ohm, one-turn Helipot, also driven from the 30-rpm shaft.

Not only did the resulting control system function well in all tests, but additional applications became apparent with use. Creep tests of plastics, nonmetallic specimens, and spot-welded or riveted assemblies which do not lend themselves to resistance heating are also possible. In this case, five to 15 quartz lamps connected in parallel are substituted for the transformer and placed close to the specimen. This method provides heating rates up to 100 deg F per sec for a 0.063-in. stainless-steel specimen.

Bomarc Data Dubbing Technique Is Precise, Simple

HAROLD M. KRIEGER
Boeing Airplane Co.

Missile flight data is recorded on magnetic tapes during the flight and analyzed later. The data reduction department often makes a Fourier analysis of the variations in a particular measurement during a certain part of the test flight. To do this, the portion of the original tape recording which contains the data to be analyzed is rerecorded or dubbed onto a short tape loop. This loop is then played back over and over by an automatic Fourier analyzer that slowly scans all frequencies from 3 to 2,000 cps, producing a special chart on a direct-writing oscillograph of the amplitude of each frequency-component vs. frequency.

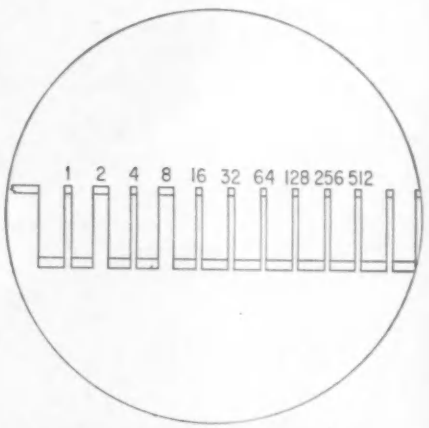
Dubbing of the original recording to the short loop requires that the "record" relays in the tape loop transport be precisely synchronized to close at the desired instant of the test data and carefully timed to open when the loop is full. Loop length and loop speed are chosen to include the necessary interval of data. These operations are performed in Boeing's Data Reduction Dept. by a preset synchronized counter and an electronic interval timer. Recognition of the precise second in which the dubbing is to begin, however, is left to a human operator to avoid code translation problems.

Specially coded timing signals are recorded on the original tape during the missile flight, identifying precisely the beginning of each second of flight. The code used is a sequence of width-modulated pulses, at 100 pulses per sec. A binary zero is represented by a 2-millisec-long pulse, and a one by a 6-millisec pulse. The beginning of each second is marked by a 10-millisec pulse which is not part of the code.

In the technique used at Boeing, the time signal is connected to the Y input of a long-persistence oscilloscope via an RC integrating network. The time base is then adjusted to make the pulses fall under the numbered intervals on a clear plastic mask, as seen in the figure. The operator can then read the previous time interval by summing the values of the wide pulses. The tenth second is illustrated.

If it is desired to dub the flight data recorded between 16.3 and 17.3 sec of a missile flight, a tape loop would first be made that would run exactly 1 sec at normal speed; e.g., 60 in. at 60 ips. The operator would then start the original tape and the tape loop running, while observing the time code on the oscilloscope. When the 15-sec code appears, the operator closes a switch that enables a preset counter to begin counting at the start of the 16th second. A multivibrator in the preset counter divides down the 100 pps to 10 pps. The preset counter counts three of these pulses and closes the record relay, which simultaneously energizes the interval timer.

The interval timer is usually set to slightly more than the interval desired, say 1.15 sec in this case, to overlap the beginning of the data and completely fill the loop for a good, clean end of recording. To do this, the recorder must saturate the tape.



Scope display of width-modulated pulse code time signal from flight-test tape looks like this to operator of data reduction equipment during playback of tenth second of test.

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Proved by over 16,000,000 printings without repairing, adjusting or cleaning!

The adding machine in the Digit-Matic has been tested with over 16,000,000 continuous printings, with no failure, no service other than periodic oiling. Forty years of experience in producing 1,500,000 adding machines—as well as precision instruments such as the Norden Bombsight—has given Victor Adding Machine Co. outstanding qualifications for producing rugged and reliable digital printers.

CHECK THESE 4 VICTOR ADVANTAGES

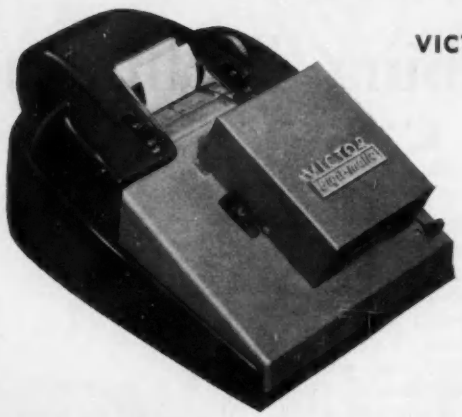
Reliability: Examine the rugged construction of a Victor machine. Each part is conservatively designed to provide extended life and reliability. Wearing surfaces heat treated, cyanide hardened to stand up under constant use. All steel parts cadmium plated to prevent rusting.

Immediate Service: Factory-trained servicemen (and parts) are on call in more than 725 cities coast to coast.

Flexibility: At least 500,000 different combinations available, with speeds up to 33 characters per second. With Victor Digit-Matics you have your choice of listers, accumulators, or calculators *plus* an almost infinite number of other variations ranging from electrical noise filters to upside-down printing.

Fast Delivery, Low Price: Because of Victor's continuous high volume of adding machine production, we can ship almost any quantity of Digit-Matics—built specifically to your order—within 30 days. Victor Digit-Matics, from only $425.00, are the value buy in the digital printer field.

IN OPERATION—BOOTH 1210—WESCON SHOW



VICTOR SERIAL ENTRY DIGIT-MATIC PRINTER

10 Digit solenoids. Digits are entered in sequence with most significant digit first. Accepts digits at a rate up to 20 per second. Print cycle: listers 0.27 seconds; accumulators 0.35 seconds. Available in up to 11 column entry capacity.

COIL DATA

Voltage	21-28VDC	42-54VDC	125-160VDC
Resistance, ohms			
Digit solenoid	25.5	75.0	490.
+ or − Print solenoid	25.5	75.0	450.
Minimum on time, seconds	.02	.02	.02
Maximum on time, seconds (continuous printing)	.05	.05	.05

Minimum off time between digits—all serial entry machines—.025 seconds.



COVER REMOVED

VICTOR PARALLEL ENTRY DIGIT-MATIC PRINTER

All digits 1 through 9 of each column equipped with solenoids. Digit and print command solenoids may be simultaneously energized. Print cycle:—listers 0.30 seconds; accumulators 0.35 seconds. Available in up to 10 columns entry capacity.

COIL DATA

Voltage	20-28VDC	35-56VDC	125-160VDC	105-125VAC
Resistance, ohms				
Digit solenoid	17.6	53.0	700.	125.
+ Print solenoid	17.6	89.0	375.	125.
− Print solenoid	17.6	53.0	375.	125.
Minimum on time, seconds	.020	.020	.015	.025
Maximum on time, seconds (continuous printing)	.050	.050	.035	.050

A few popular model variations:—columnar spacing; right side of machine accumulating and left side listing data identification; Non-Add printing; Non-printing adding; MIL-I-17623 Electrical Motor Noise elimination; Induction Motors; Manual Keys over the solenoids; "digit key depressed" switch (serial entry Digit-Matics); tag and label printing; and all kinds of alphabetic and special types.

Write today! Victor's electronics-trained staff will gladly help you solve any digital printing or calculating problem.

Write for technical manual No. B8-71.

Electronics Division

VICTOR ADDING MACHINE CO.

3900 N. Rockwell Street, Chicago 18, Ill.

Simple Controls Can Eliminate Product Damage

Ethicon, Inc. manufactures more than 100 million ft of absorbable medical sutures each year. These sutures, made from animal intestines, are absorbed by the body tissues during the healing process. They are made to be absorbed fast or slow, and in various diameters.

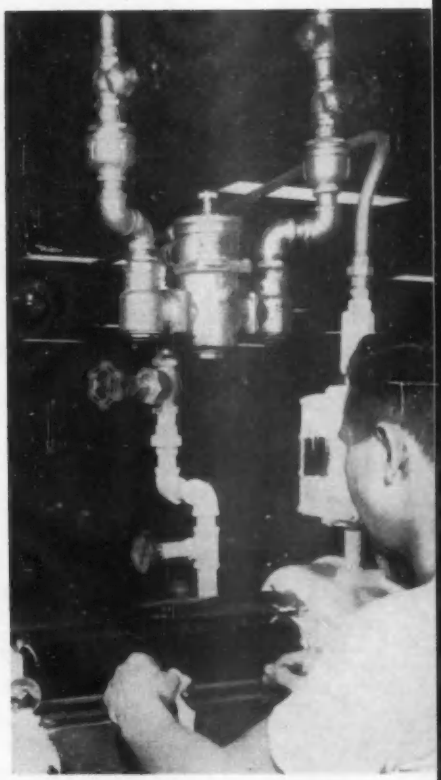
During manufacture the intestinal material is cleaned by washing in hot water. The temperature of the water ranges from 100 to 119 deg F, depending on the type and thickness of the intestine being processed. If the water is hotter than the prescribed temperature, the material will cook; if it is colder the mucous in the intestines will not be thoroughly removed.

Water temperature in the cleaning machines used to be controlled manually. But temperature changes caused by water being turned on and off in other parts of the plant were too fast to check, with the result that suture damage caused by water temperature fluctuation amounted to several percent of the plant's total suture damage.

Installation of thermostatic water controls on each of the machines in place of hand valves reduced temperature fluctuations to within 1 deg F and completely eliminated the suture damage from this cause. The controls used were Powers Regulator Type N Hydroguards. The water rate is 10 to 20 gpm.

After passing through the hot water, the intestines are placed in processing tanks 34 ft long, that hold 200 gal of liquid, a combination of chemical and water. The temperature has to be held at 105 deg F to get the desired washing and processing action. A thermostatically controlled electrical heater on each tank normally maintains this temperature.

The tanks are emptied and cleaned daily, however, and filled each morning with a hose. If the liquid used to fill the tanks is not at the proper temperature, there is too much of a delay before the tank heaters can bring the temperature up or room temperature can bring it down. A 40-gpm Hydroguard now holds the liquid temperature during filling of the tanks to within 1 deg F, and eliminates the delay, resulting in more efficient production.



Simple installation of automatic thermostatic mixing controls (top of picture) on water line to cleaning machine has completely eliminated product damage for manufacturers of medical sutures.

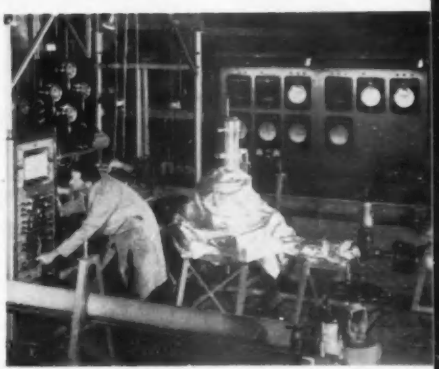
Complex Controls Can Pay in Production-Testing

Flow control valves for the coolant circuits of pressurized-water atomic reactors have to operate at high temperatures and pressures, any variations of which can affect the rate of leakage through valve gates, seats, and cylinder rings. In a $150,000 heavily instrumented stainless steel hot-test loop for testing production valves, developed by Crane Co., expected operating conditions are reproduced exactly and all important variables are recorded simultaneously by a six-channel direct-writing oscillograph manufactured by Brush Instruments.

There are three loop test stations, so that a valve can be set up while a second is being tested and a third is being dismantled.

The main flow loop connects the inlet and outlet valve connections at each of the test stations to a pair of surge tanks by way of a 10-hp canned pump. The stainless-steel canned pump operates hermetically sealed, and circulates water inside the main loop at a pressure differential of 75 psi. Operating pressure of 1,500 psi in the main flow loop is built up by compressed air in the top of the surge tanks. Water for the system is first purified and deionized, then preheated in an 80-gal gas-fired glass-lined tank and pumped into the loops as needed.

Water level in the surge tanks, water temperature, loop pressure, and differential pressure across the canned pump are all automatically controlled by the instruments on the large panel behind the pump in the photograph. Temperatures of the valve body and actuating cylinder, and pressure differentials and leak rates around the seat, stem guide, and piston are recorded simultaneously during each test. The recorder, at left in the photograph, is mounted with its amplifiers in a wheeled rack that is easily moved from one test station to another. The six-channel test chart produced during test of each valve is retained by Crane, and a written test record supplied to the customer.

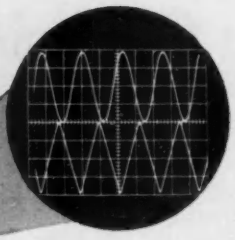


One of three test stations in controlled hot-test loop. Production valve being tested (under insulating blanket) is a coolant flow control valve for submarine atomic reactor.

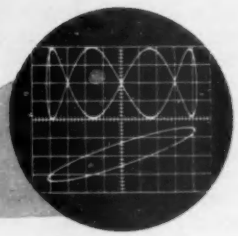
NEW DUAL-BEAM OSCILLOSCOPE

Tektronix Type 502

- TWO-GUN CATHODE-RAY TUBE.
- 200 μv/cm SENSITIVITY, BOTH BEAMS.
- DIFFERENTIAL INPUT, ALL SENSITIVITIES.
- 2, 5, 10, and 20 TIMES SWEEP MAGNIFICATION.
- CURVE TRACING with TWO BEAMS—(horizontal input sensitivity to 0.1 v/cm).
- SINGLE-BEAM CURVE TRACING at 200 μv/cm, BOTH AXES.
- EXTRA FEATURE—Both amplifiers have transistor-regulated parallel heater supply.



Dual display on linear time base.



Dual display for X-Y curves.



Here are a few uses for the Type 502:

IN ELECTRONICS—Use the Type 502 as a general-purpose oscilloscope and also to show simultaneously the waveforms at any two points in a circuit, e.g. input and output, opposite sides of a push-pull circuit, trigger and triggered waveform, etc.

IN MECHANICS—Display, compare, and measure outputs of two transducers on the same time base; plot one transducer output against another—pressure against volume or temperature for instance; measure phase angles, frequency differences, etc.

IN MEDICINE—Display, compare, and measure stimulus and reaction, or the outputs of two probes, on the same time base; use differential input to cancel out common-mode signals, or to eliminate the need for a common terminal; use in routine investigations, etc.

IN ALL FIELDS—The Type 502 can save you more than its cost in time—in as little as one application!



TYPE 502 CHARACTERISTICS

HIGH-GAIN AMPLIFIERS

200-microvolts/cm deflection factors, both dc-coupled and ac-coupled. 16 calibrated steps from 200 μv/cm to 20 v/cm.

Passbands— dc-to-100 kc at 200 μv/cm, increasing to dc-to-350 kc at 1 mv/cm and dc-to-500 kc at 50 mv/cm to 20 v/cm.

Differential Input, Both Channels—Rejection ratios: 1000-to-1 at 1 mv/cm or less, 100-to-1 at 0.2 v/cm, 50-to-1 at 5 to 20 v/cm.

Constant Input Impedance (1 megohm, 47 μμf) Both Channels—from 1 mv/cm to 20 v/cm, for use with Tektronix P510A Probes. (2-P510A Probes furnished).

WIDE-RANGE SWEEP CIRCUIT (Common to both beams)

Single-knob control for selecting any of 22 accurately-calibrated sweep rates from 1 μsec/cm to 5 sec/cm.

Sweep Magnification—2, 5, 10, and 20 times, accurate within the maximum calibrated sweep rate.

Automatic Triggering—fully automatic, or preset with amplitude-level selection when desired. Sweep can also be operated free-running.

X-Y CURVE TRACING OPERATION

Horizontal-input amplifier permits curve-tracing with both beams simultaneously at sensitivities to 0.1 v/cm. For curve tracing at higher sensitivities (to 200 μv/cm) with one beam, one of the vertical amplifiers can be switched to the horizontal-deflection plates.

OTHER FEATURES

Amplitude calibrator, 1 mv to 100 v in decade steps—square wave, frequency about 1 kc.

3-kv accelerating potential on new Tektronix 5" dual-beam crt. 8-cm by 10-cm linear-display area, each beam.

Electronically-regulated power supplies. Price $795

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TEKTRONIX ENGINEERING REPRESENTATIVES: Arthur Lynch & Assoc., Ft. Myers, Fla., Gainesville, Fla.; Bivins & Caldwell, Atlanta, Ga., High Point, N. C.; Hawthorne Electronics, Portland, Ore., Seattle, Wash.; Hytronic Measurements, Denver, Colo.

Tektronix is represented in 20 overseas countries by qualified engineering organizations.

NEW PRODUCTS

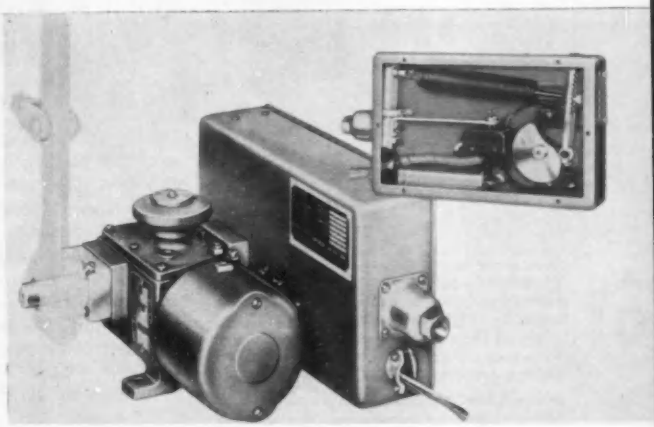
LISTING IN GROUPS

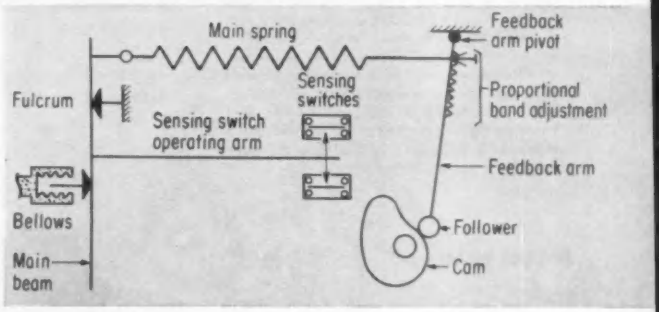
Designs of the Month
Data Handling & Display
Primary Elements & Transducers
Controllers, Switches & Relays
Power Supplies
Actuators & Final Control Elements
Research, Test & Development
Accessories & Materials

RUGGED REGULATOR offers special drive.

The accompanying photo and schematic illustrate the construction and operation of a new Master Regulator, designed for temperature or pressure control applications. Electrically operated and highly sensitive, the device includes a special drive motor that can be stalled indefinitely and continuously reversed.

Features listed by the manufacturer are: complete electromechanical operation, simple electrical connections, dust-tight construction, integral-cast-iron motor housing and gear case, and simple linkage arrangements. Geared output of the heavy-duty capacitor start-and-run motor may be used to operate dampers, fuel valves, and similar equipment. For boiler-room applications, the device offers complete compatibility with all flame failure and safety equipment.





Characteristics:

Sensitivity: 0.25 percent of operating range
Deadband: adjustable from 1 to 25 percent of set-point
Response speed: 30 sec for full travel
Pressure range: as required, up to 600 psi
Temperature range: as required
Torque: 204 to 12,000 lb-ft, depending on model
Power required: 115 volts, 60 cps, single phase, 1 amp
Weight: 25 lb
–Optimum Control Corp., Cleveland, O.

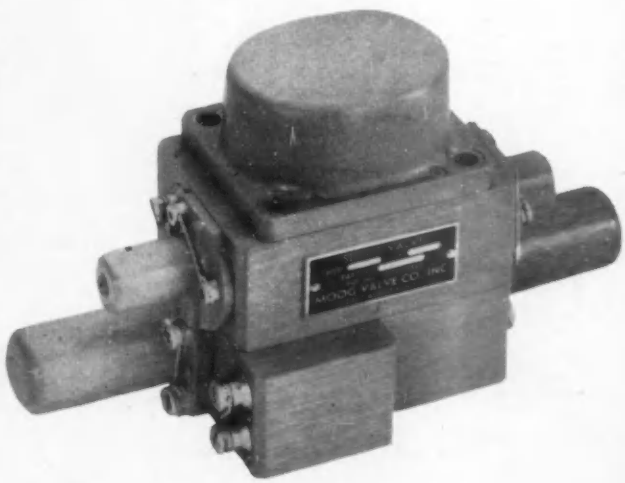
Circle No. 1 on reply card

NEW SERVOVALVE improves performance.

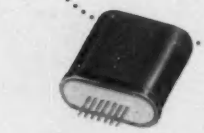
Called a Dynamic Pressure Feedback (DPF) Valve, this Series 16 servovalve facilitates damping of high inertia resonant loads in hydraulic servos. In addition to providing improved closed-loop dynamic performance, it will maintain high static stiffness. By feeding back cylinder differential pressure through an internal frequency-sensitive hydraulic network, the valve provides controlled dynamic pressure-flow characteristics. Sensitivity of flow to load pressure can be tailored to provide optimum damping.

While the technique produces an effect similar to that of a piston by-pass orifice, valve characteristics are more linear and power dissipation is eliminated. At low frequencies, the DPF Valve functions as a standard flow control valve to provide the high system stiffness.–Moog Valve Co., Inc., East Aurora, N. Y.

Circle No. 2 on reply card

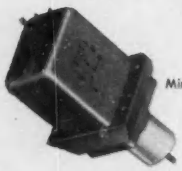


Three different relays with *one* thing in common . . .



Sub-Miniature Relay Type 95





Miniature Telephone-Type 115

High Voltage Relay Type 134-3468

Sure, these three relays were obviously built for three very different applications—yet they have one common denominator—AEMCO ingenuity. Originally developed to meet rigid electrical and mechanical requirements, these three relays are typical of AEMCO engineering and production facilities.

Although AEMCO manufactures a wide variety of relay types now available as "standards," custom development and manufacture to tight tolerances are AEMCO specialties. Want fast delivery on prototypes? Want outstanding engineering and production facilities at your disposal? Then, send us the specifications on your next relay—we may have an AEMCO "standard" that will save you tooling and valuable time—or if your problem is development, we'll be happy to design a relay to meet your specific requirements.

Need relays? ask AEMCO



AEMCO offers a complete line of relays in a wide choice of spring and coil combinations, operating potentials, and contact ratings. If one of hundreds of standard AEMCO relay types does not exactly meet your requirements, we will be happy to design and manufacture a unit to meet or exceed your requirements.

AEMCO also manufactures a complete line of Sequence and Automatic Re-Set Timers, Time Switches and Sign Flashers.

WRITE TODAY

Your inquiries are invited. Ask for your free copy of Relay Catalog describing all standard relays in the AEMCO line.

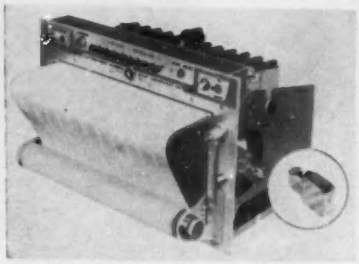


AEMCO INCORPORATED

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NEW PRODUCTS

DATA HANDLING & DISPLAY



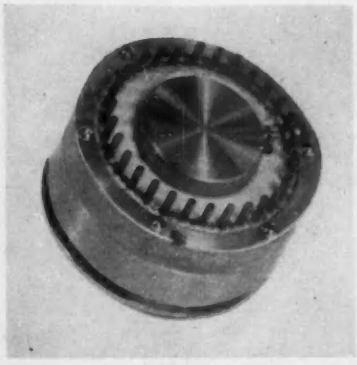
12-CHANNEL RECORDER

Developed to meet the need for a compact, high-speed, multichannel instrument, the Model RE-12 recorder offers true rectilinear motion and excellent transient response. A convenient plug-in control unit makes possible remote operation. An event marker provides 1-sec markings and a footage indicator shows the amount of chart remaining in the recorder.

Characteristics:

Frequency range: dc to 200 cps
Chart speeds: 18, from ½ cm per hour to 200 mm per sec
Sensitivity: 20 ma rms, full-scale
Impedance: 1,000 ohms nominal
—Massa Laboratories, Inc., Hingham, Mass.

Circle No. 3 on reply card



LIGHTWEIGHT SAMPLER

This tiny rotary sampling switch weighs only 2.37 oz, and is ¾ in. long and 1¼ in. in diam. Called the Miniplexer, it has 60 contact pins for 30 channels of make-before-break operation, provides 500 service-free hours at 30 rps, and will operate under vibration conditions of 2,000 cps at 25 g's. It replaces a model that was five times heavier and much larger.—Applied Science Corp. of Princeton, Princeton, N. J.

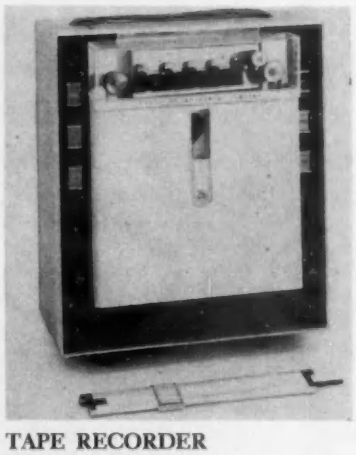
Circle No. 4 on reply card



EASIER TO READ

Suitable for switchboard or panel, a new line of ac and dc meters features a high degree of readability. Units are available in 2½ in. and 3½ in. sizes. All dc instruments are self-shielded, and all dc ammeters except those below 5 ma use a new moving-magnet mechanism. Milliammeters below 5 ma, and all microammeters use the standard core-magnet movement. A control magnet replaces the conventional control springs, eliminating the need for a zero set. Company claims an accuracy of within 2 percent full-scale for all instruments.—General Electric Co., Schenectady, N. Y.

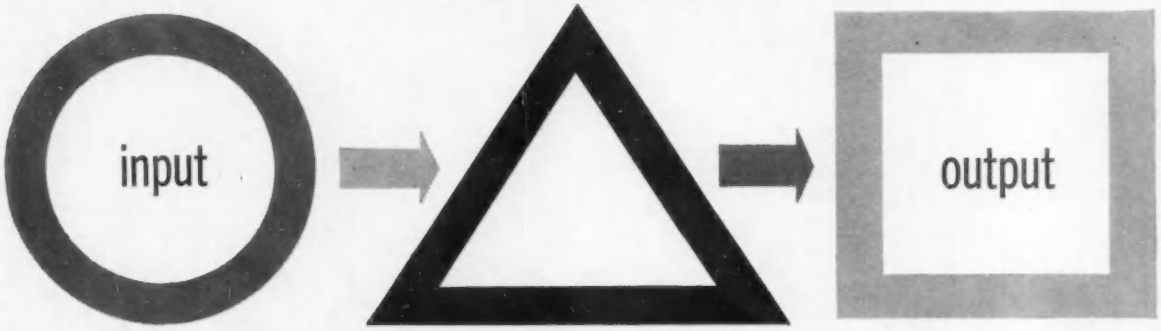
Circle No. 5 on reply card



TAPE RECORDER

Built to rigid performance requirements of military and industrial telemetering, a new tape-record-reproducer unit gathers, records, reduces, and stores data. Modular construction pro-

measure control... without contact...



Now—measure pressure, temperature, vibration . . . any physical quantity you can convert to a change in capacitance . . . without fuss, muss, or bother. Decker's Delta Unit takes the output from the simplest △ capacitance sensors you can devise, converts it to an analagous phase sensitive differential DC voltage for indication and recording.

The new 902-1 Delta Unit is based on Decker's patented T-42 Ionization Transducer. It provides all the advantages of the T-42 ready to use in a simple, compact package as versatile and flexible as your own imagination.

Accepting initial capacitances from 1 to 50 μμF, the 902-1 provides maximum signals of ±30 VDC. Sensitivity in the 5-20 μμF initial capacitance range is approximately 0.2V/% △ C. Unit is provided with a single measuring probe and cable assembly; however, two measuring probes may be operated simultaneously. Complete information is provided in Instrument Data Sheet 902-1, available on request.



THE DECKER CORPORATION *Bala Cynwyd, Pennsylvania.*

NEWS ABOUT
BENDIX SHAFT ENCODERS

Photo-Electric Sensor Types Added to Line

The Bendix® "Supermarket" for precision components has long served your analog-digital converter needs with miniature, brush slip-ring shaft encoders featuring extremely high resolution. Now, with the addition of new photo-electric sensor types, the Bendix shaft encoder line makes Bendix extra quality available for even broader applications.

With these new photo-electric sensor units, you enjoy the important advantages of higher operating speeds, lower operating torque requirements, longer life, and finer resolution in relation to physical size.



The specification table below is the best evidence we know that your shaft encoder needs find their most efficient answer at the Bendix Supermarket.

District Offices: Burbank and San Francisco, Calif.; Seattle, Wash.; Dayton, Ohio; and Washington, D. C. Export Sales & Service: Bendix International Division, 205 E. 42nd St., New York 17, N. Y.

BENDIX OFFERS WIDE CHOICE TO FIT YOUR EXACT SHAFT ENCODER NEEDS

TYPE NO.	GS-7-A1	GS-8-A1	GS-5-A1	GS-3-A1	GS-4-A1	GS-6-A1
OUTPUT	9 DIGIT GRAY	13 DIGIT BINARY	8 DIGIT GRAY	9 DIGIT BINARY DECIMAL (GRAY)	7 DIGIT BINARY	13 DIGIT GRAY
STYLE	PHOTO-ELECTRIC	DOUBLE BRUSH	BRUSH	BRUSH	DOUBLE BRUSH	BRUSH
RESOLUTION	1 PART IN 512	1 PART IN 8192	1 PART IN 256	1 PART IN 198	1 PART IN 128	1 PART IN 8192
MILLI-AMPS/DIGIT	.075 (MAX.)	10 (MAX.)	10 (MAX.)	15 (MAX.)	10 (MAX.)	10 (MAX.)
CONT. SPEED (RPM)	HIGH SPEED†	150 (MAX.)	150 (MAX.)	150 (MAX.)	150 (MAX.)	50 (MAX.)
OPERATING TORQUE	.05 OZ-IN. (MAX.)	.50 OZ-IN. (MAX.)	.20 OZ-IN. (MAX.)	.22 OZ-IN. (MAX.)	.31 OZ-IN. (MAX.)	.40 OZ-IN. (MAX.)
CASE DIAMETER	1.191 INCH	1.411 INCH	.937 INCH	.937 INCH	.937 INCH	2.50 INCH

†RPM DETERMINED BY APPLICATION



*You Can't Beat The Bendix Supermarket.

Eclipse-Pioneer Division

Bendix AVIATION CORPORATION

Teterboro, N. J.

NEW PRODUCTS

vides easy access to components for service and inspection.

Characteristics:

Response range: dc to 120 kc
Signal-to-noise ratio: better than 50 db for fm and 40 db for am
Speeds: six, from 1⅞ to 120 ips
Capacity: two to 28 tracks recorded simultaneously
—Telectro Industries Corp., Long Island City, N. Y.

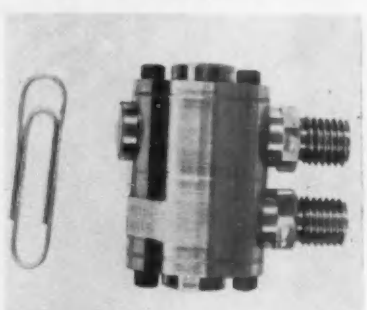
Circle No. 6 on reply card

PLUS . . .

(7) An **electronic transcribing and recording system,** developed by **Minneapolis-Honeywell Regulator Co.** at Beltsville, Md., can handle up to 10,000 pieces of information per sec. . . . (8) **Telemeter Magnetics, Inc.,** Los Angeles, Calif., offers a new **magnetic core memory unit** for converting data from punched cards to a form suitable for use in serial devices. . . . (9) **Brush Instruments,** Cleveland, Ohio, has announced a brand new eight-channel **ultralinear recording system** that features both rectilinear readout and thermal writing. . . . (10) Specifications on a new, compact, completely transistorized **perforated tape strip reader** have just been released by **Potter Instrument Co., Plainview, N. Y.**

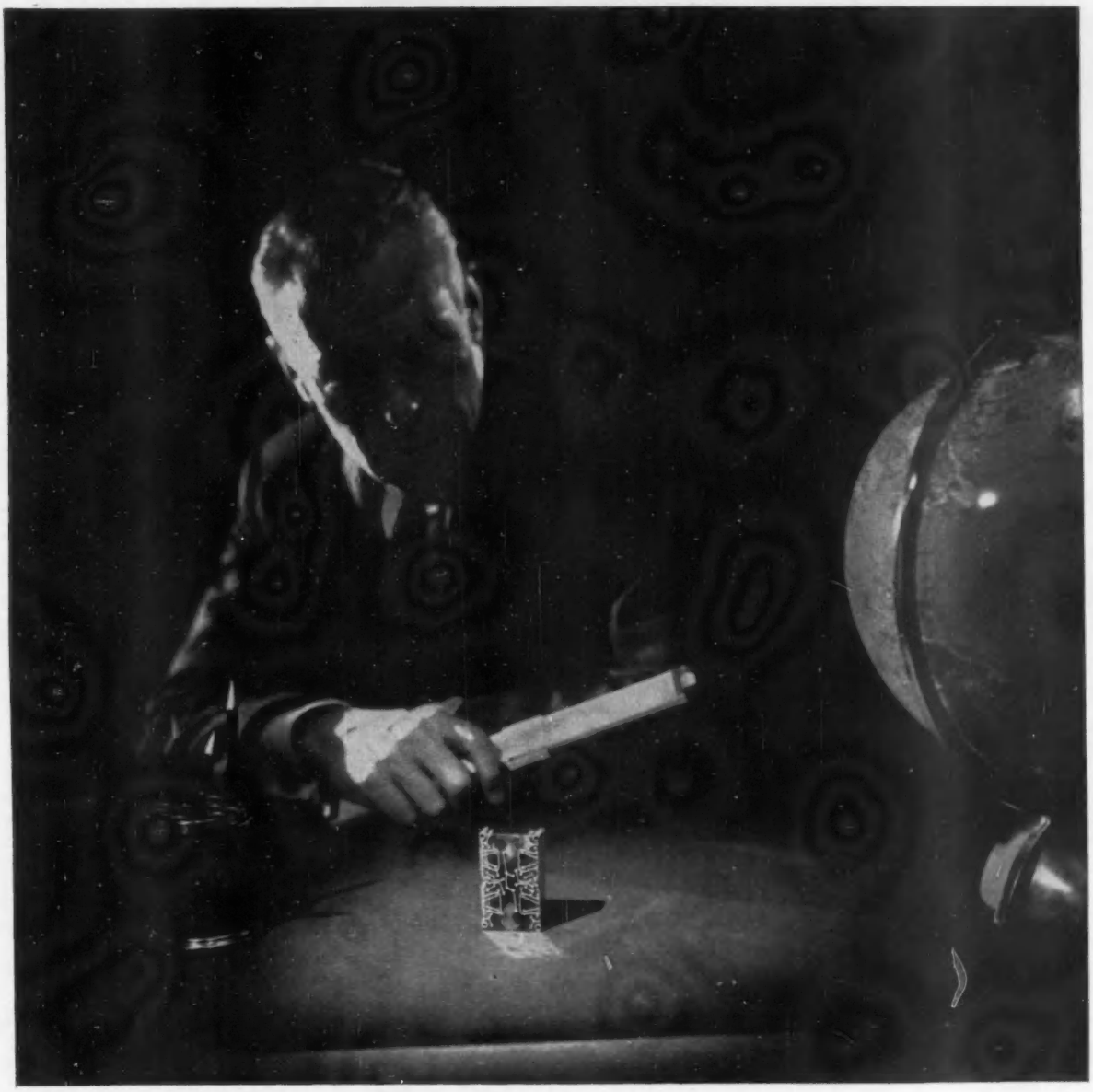
Circle No. 7, 8, 9, or 10 on reply card

PRIMARY ELEMENTS & TRANSDUCERS



ADJUSTABLE RANGE

A new adjustable-range pressure transducer, of the double-coil variable reluctance type, uses a flat diaphragm as its pressure-sensing element. Suitable



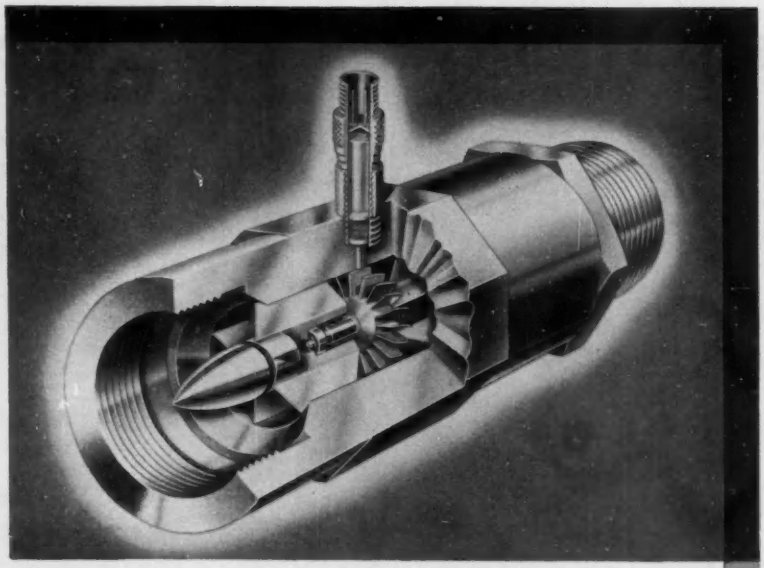
It takes brains . . .

to guide a missile . . . mechanical brains, that is, like this tough but tiny *ARMA* digital computer module. *ARMA* has put a great many brains to work designing a fully transistorized and miniaturized digital computer, a critical part of *ARMA*'s all-inertial guidance system for the Air Force ICBM Program.

More brains, the human kind, are now needed for *ARMA*'s inertial role in the Air Force ICBM Program. Specialized senior engineering and technical management positions with excellent growth potential are now available. Write to *ARMA* . . . Professional Personnel, Garden City, N. Y. Prompt, convenient, confidential interviews.

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★ Meticulously calibrated to insure 1/2% accuracy
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new COX turbine flowmeter

For over 46 years the name "Cox Instruments" has been synonymous with *precision* flow measurement. Such outstanding equipment as Cox Variable-Area Flowmeters and Cox Calibrating Stands have helped make it possible for industry to establish realistic standards for accuracy and reliability in flow measurement.

And now . . . the Cox *Turbine* Flowmeter joins this list of truly precision products. Developed to meet the exacting needs of modern instrumentation systems, it has received the acclaim of initial users throughout industry.

We welcome the opportunity to tell you more about the complete line of Cox Turbine Flowmeters. Write to *Cox Instruments Division, George L. Nankervis Company, 15200 Fullerton Avenue, Detroit 27, Michigan.*

COX

A new technical bulletin describes the complete line of cox turbine flowmeters. Ask for bulletin no. 2300c.



INSTRUMENTS

Precision Instruments Since 1912

GLN-1259

NEW PRODUCTS

for applications requiring small size, high response, and resistance to severe environmental conditions, the unit translates gas or liquid pressure to proportional electrical signals. Features include adjustable sensitivity and provision for evacuation immediately before use. The transducer is just $\frac{7}{8}$ in. in diam and $1\frac{3}{8}$ in. long, and weighs less than $2\frac{1}{2}$ oz.—Yuba Consolidated Industries, Inc., San Francisco, Calif.

Circle No. 11 on reply card



"POTTED" COMPONENTS

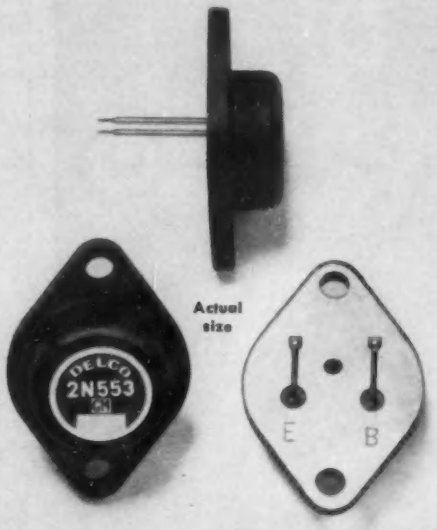
This new line of variable inductance pressure transducers measures pressure in conducting fluids such as salt water. It features "potted" components and connections. Models are available in differential, gage, and absolute ranges from 0 to 10 psi to 0 to 3,500 psi. Outputs can be expressed as variable frequency, ac or dc voltages.—Datran Electronics, Manhattan Beach, Calif.

Circle No. 12 on reply card

PLUS . . .

(13) **Tiny tri-axial accelerometers,** with sensitivities up to 27 mv per g, are available from **Columbia Research Laboratories, Woodlyn, Pa.** . . . (14) **Dynac, Inc.,** Palo Alto, Calif., offers the DY-2504A **photoelectric tachometer** for sensing speeds between 0 and 10,000 rmp. . . . (15) **Ultradyne, Inc.,** Albuquerque, N. M., has designed a **pressure transducer** for measuring differential pressure in liquid oxygen and other cryogenic fluids. . . . (16) Trimmed drift rates of 0.1 deg per hour are guaranteed in a new series of 20 single-axis floated **integrating gyros** manufactured by **Reeves Instrument Corp.,** Garden City, N. Y.

Circle No. 13, 14, 15, or 16 on reply card



ANNOUNCING...

the newest addition to the Delco family of PNP germanium transistors! It's ideally suited for high-speed switching circuits and should find wide use in regulated power supplies, square wave oscillators, servo amplifiers, and core-driver circuits of high-speed computers. It's the 2N553!

NEW HIGH-FREQUENCY POWER TRANSISTOR BY DELCO

No other transistor offers so desirable a combination of characteristics for applications requiring reliability and consistency of parameters.

TYPICAL CHARACTERISTICS T = 25°C unless otherwise specified

Collector diode voltage V_{CB} (V_{EB} = −1.5 volts)	80 volts maximum
Emitter diode voltage V_{EB} (V_{CB} = −1.5 volts)	40 volts maximum
Collector current	4 amps. maximum
Base Current	1 amp. maximum
Maximum junction temperature	95°C
Minimum junction temperature	−65°C
Collector diode current I_{CO} (V_{CB} = 2 volts)	12 μa
Collector diode current I_{CO} (V_{CB} = −60 volts)	0.5 ma
Collector diode current I_{CO} (V_{CB} = −30 volts, 75°C)	0.5 ma
Current gain (V_{CE} = −2 volts, I_C = 0.5 amp.)	55
Current gain (V_{CE} = 2 volts, I_C = 2 amps.)	25
Saturation voltage V_{EC} (I_B = 220 ma, I_C = 3 amps.)	0.3
Common emitter current amplification cutoff frequency (I_C = 2 amps. V_{EC} = 12 volts)	25 kc
Thermal resistance (junction to mounting base)	1° C/watt

BRANCH OFFICES

Newark, New Jersey
1180 Raymond Boulevard
Tel: Mitchell 2-6165

Santa Monica, California
726 Santa Monica Boulevard
Tel: Exbrook 3-1465

DELCO RADIO Division of General Motors
Kokomo, Indiana

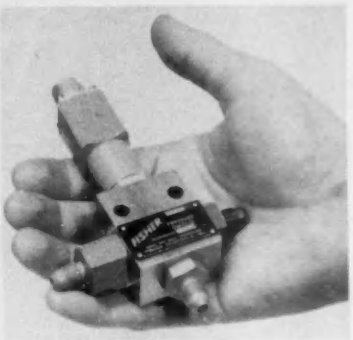
it powers the
highest performance
automatic contour
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NEW PRODUCTS

CONTROLLERS, SWITCHES & RELAYS



ADJUSTABLE, LIGHTWEIGHT

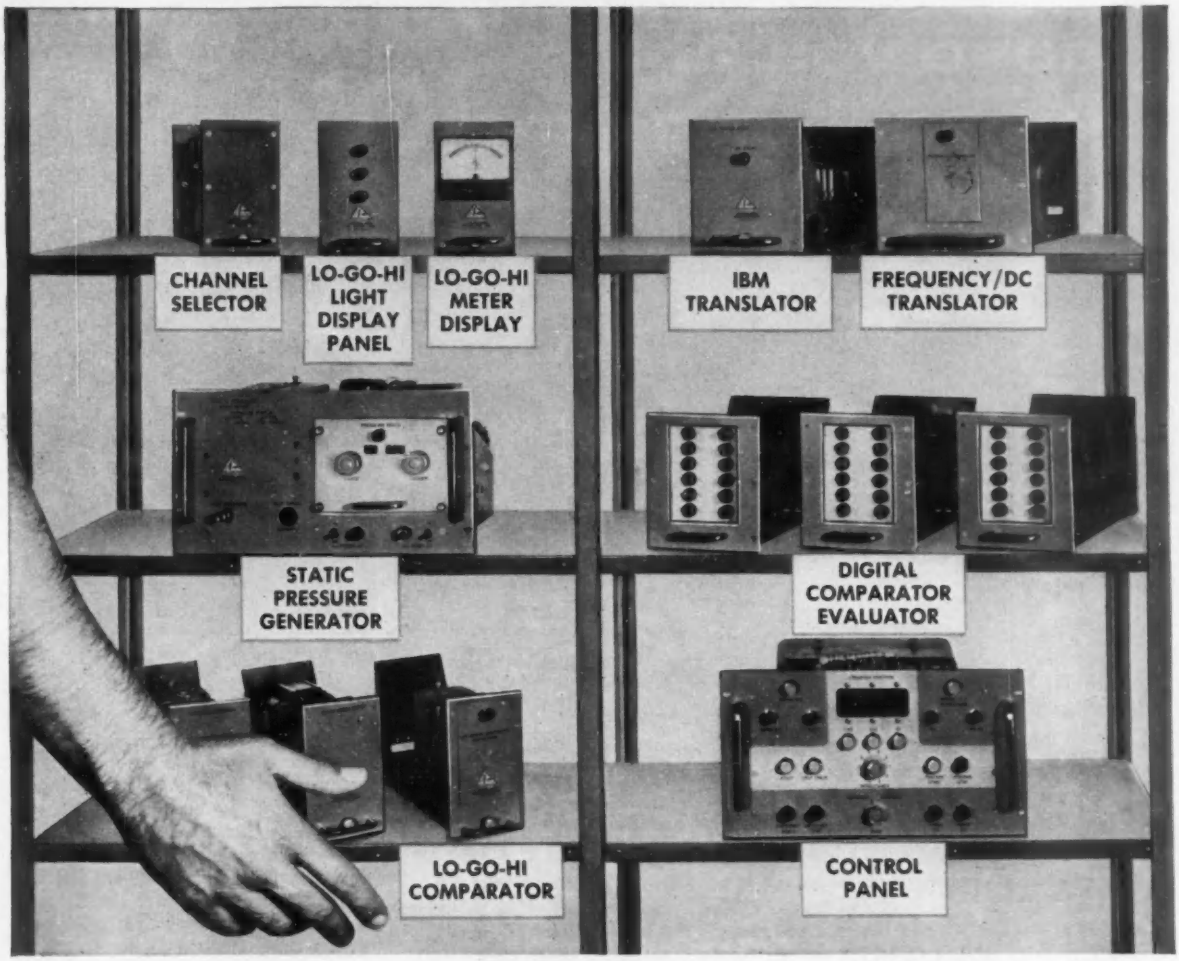
Shown is a 6-oz, fully adjustable differential-pressure switch for hydraulic and pneumatic systems. Unaffected by vibration or jarring, the unit will operate on any preset differential pressure between 10 and 2,000 psi in a system having a maximum pressure of 5,000 psi. Temperature range extends from minue 65 to 165 deg. F.—Fisher Controls, Inc., Santa Monica, Calif.

Circle No. 17 on reply card



SPEED MONITOR

A complete line of speed-sensitive switches is now available in a brand new body style for mounting directly on a standard SAE tachometer-take-off. Hex-shaped shank has a $\frac{7}{8}$-1 internal thread. To compensate for possible misalignment, the drive shaft floats in the center of this shank. Photo shows a single-element switch,



A few of the modules now available

Now...modular components for automatic weapons testing systems come

off the shelf from AMF!

It's called MATE – Modular Automatic Testing Equipment–for go no-go readout, the first significant step in eliminating obsolescence in automatic testing systems.

After extensive surveys, AMF found all automatic systems, regardless of type or complexity, can be reduced to the same, basic, packageable components.

Wide range available. AMF has already designed and produced 19 of these modules–each one a self-sufficient package with a distinct responsibility. Available to you on an "off-the-shelf" basis *now* are programming and control modules, signal translator modules, comparator-evaluator modules and display devices.

Universally adaptable. These modules can be put together to implement *any* automatic testing program. Or any of them can be integrated with existing equipment of other manufacture.

Obsolescence eliminated. After serving their purpose for the system under test, MATE modules can be reintegrated into other systems requiring the same functions. The result: complete flexibility in the most complex systems; low-cost components available on a short delivery basis, pre-designed to accomplish many different tasks; modules that retain their usefulness and validity *after* the weapons system is modified. *The resulting economies to prime contractors and the military are enormous.*

AMF GOVERNMENT PRODUCTS

Government Products Group
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Your inquiries invited—Write Associated Missiles Products Co. (a division of AMF), 2709 North Garey Avenue, Pomona, Calif.; or to AMF, Government Products Office, Washington, D.C. or Dayton, Ohio; or Los Angeles, Calif.

save valuable engineering time

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This advanced "slide-rule" is a highly accurate device that permits engineering or research personnel to simulate equations or physical problems electronically, and save many hours of involved calculation.

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Because it is a kit, and you, yourself, supply the labor, you can now afford this instrument, which ordinarily might be out of reach economically. Write for full details today!

save money *with* HEATHKITS

Now for the first time, the cost of this highly accurate, time and work-saving computer need not rule out its use—You assemble it yourself and save hundreds of dollars.

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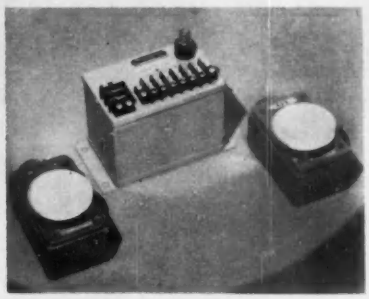


Get the complete computer story from this four-page folder, available free!

NEW PRODUCTS

either manual or automatic reset, which opens or closes a set of contacts at a preset speed. Standard governor switches can be furnished for operations between 500 and 6,000 rpm.—Synchro-Start Products, Inc., Skokie, Ill.

Circle No. 18 on reply card



SAFETY INTERLOCKS

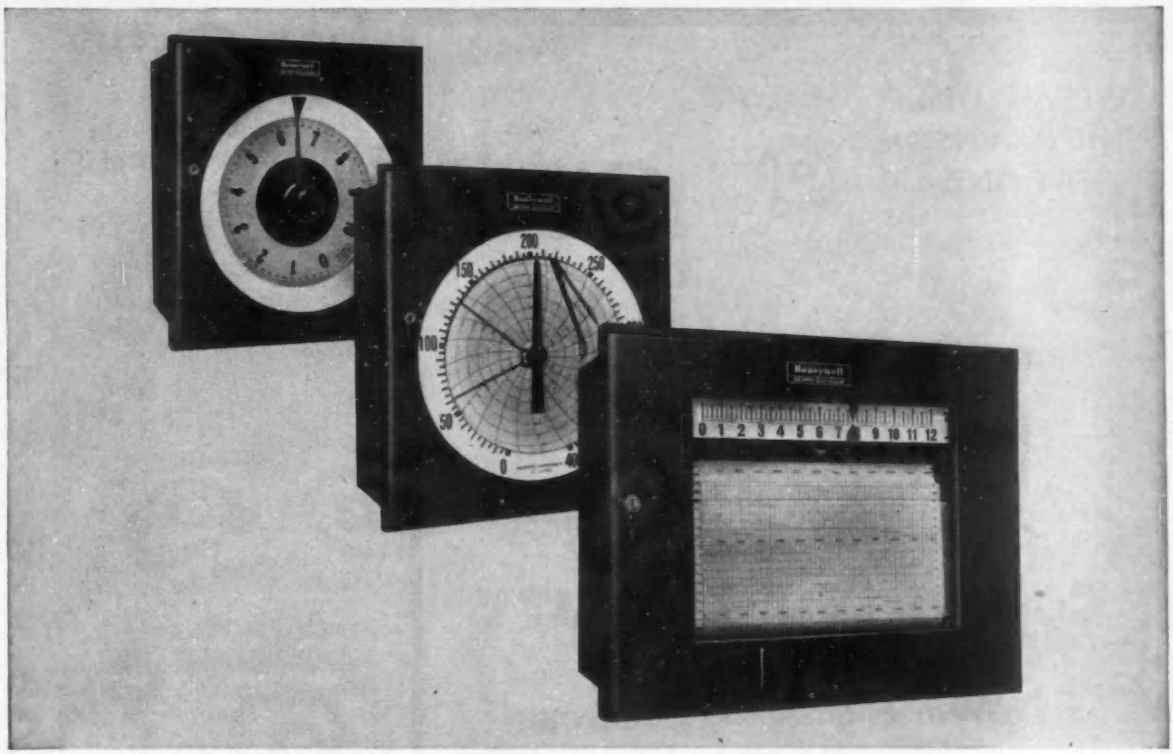
A new Cypak static safety interlock for machines with dual manual control requires simultaneous closing of two palmbuttons or other control switches. If either button is released, the machine is stopped and cannot be restarted until both buttons have been released and depressed again. Unit operates on a 117-volt, 60-cps supply and has an output power of 250 ma at 6.5 volts, half-wave dc, sufficient to drive any standard 6-volt dc relay. It is compact and tamperproof, and contains no moving parts.—Westinghouse Electric Corp., Pittsburgh, Pa.

Circle No. 19 on reply card

PLUS . . .

(20) **A rotary selector switch** that holds up to four 12-position wafers, yet weighs only 3½ oz, has been readied for miniature design applications by **G. H. Leland, Inc.**, Dayton, Ohio. . . . (21) **Robertshaw-Fulton Controls Co.**, Milford, Conn., has just released data on a new, **lightweight pressure switch** for trip pressures between 20 and 500 psi. . . . (22) The MT Series **step switch,** manufactured by **Eagle Signal Corp.,** Moline, Ill., is available with from two to 20 independent 10-amp circuits, and is driven by a rotary ac solenoid at speeds up to 300 steps per min. . . . (23) A compact **airborne commutator** built by **Wiancko Engineering Co.,** Pasadena, Calif., weighs less than 12 oz but can handle 30 channels at rates up to 2,500 samples per sec.

Circle No. 20, 21, 22, or 23 on reply card



the *ElectroniK* recorder or indicator is a thousand instruments in one

An *ElectroniK* instrument adapts easily to your changing needs, never becomes obsolete. Its remarkable versatility is made possible by the many measuring circuits . . . many types of records or indications . . . many pen or print wheel speeds . . . and the wide variety of functions that can be incorporated in the instrument.

You can convert most *ElectroniK* instruments to practically any scale, simply by soldering appropriate kit-supplied range resistors into the measuring circuits. And you have a choice of more than 575 *standard* charts and scales in strip chart instruments (similar large choice in indicators and circular chart models). You can change chart speeds from one half to four times the basic speed, with a simple gear change.

Use *ElectroniK* instruments to measure temperature, pressure, flow, pH, chemical concentration, voltage, speed—*any* variable that's translatable into a d-c signal.

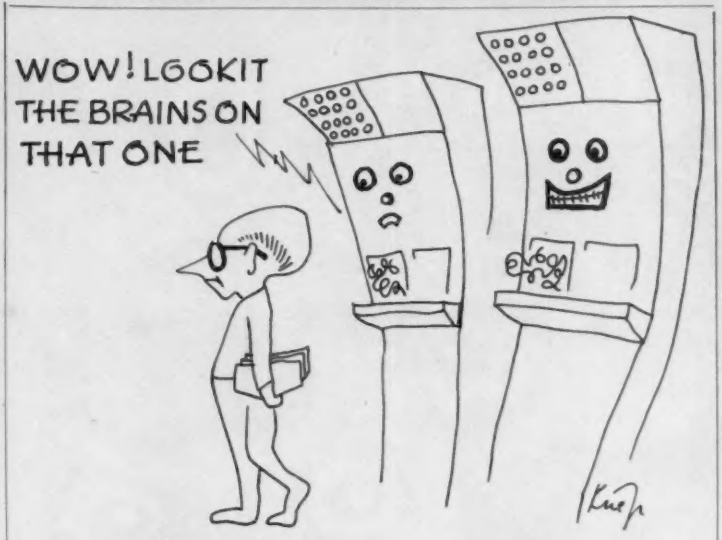
Unitized construction lets you transfer complete control units from one *ElectroniK* instrument to another. Cases are designed for both surface and flush panelboard mounting. With auxiliary switches, the instrument works in conjunction with audible or visual alarms and safety cutouts.

Your nearby Honeywell field engineer can help you gain the advantages of *ElectroniK* versatility in specific applications. Call him today. He's as near as your phone.

MINNEAPOLIS-HONEYWELL, Wayne and Windrim Avenues, Philadelphia 44, Pa.

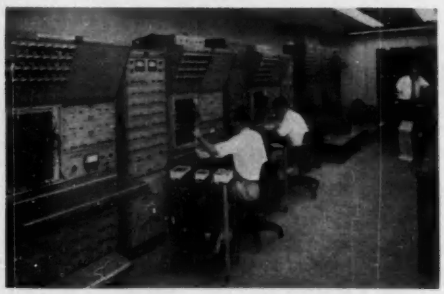
Honeywell

First in Controls



COMPUTER FACILITY

The Intelligent Approach
To Your Engineering Problems



CONTROL SYSTEM SYNTHESIS

PROCESS SIMULATION

HEAT TRANSFER

DYNAMIC ANALYSIS

STRESS AND VIBRATION

CONSISTENTLY SERVING INDUSTRY FOR MORE THAN TEN YEARS

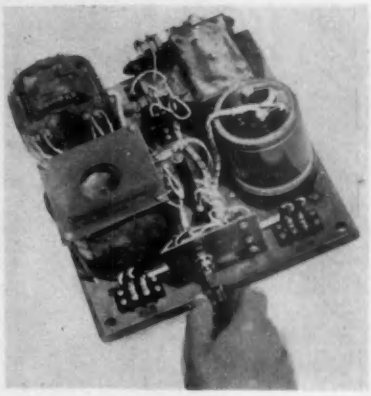
The simulation of systems and processes is of invaluable use for the optimizing of performance and control for design purposes. It confines the errors to the rapid design changes possible with simulated trials, thereby providing optimum system performance with the application of proven designs. The facility shown has been used for a wide area of engineering applications ranging from the simulation of an air hammer to a turbo-fan engine for control purposes. We will be pleased to discuss your problems, whether on a complete engineering service basis or to provide the eauipment time required by your own staff on a rental basis.

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POWER SUPPLIES



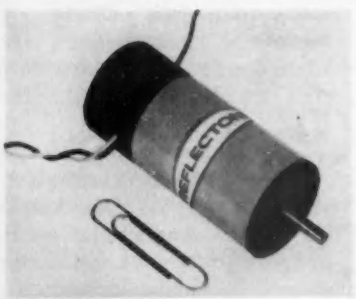
SYSTEM SUPPLY

Open-type base plate construction of this new regulated dc supply provides for flexible system design. Built for ambient temperatures between minus 65 and plus 130 deg F, the unit meets environmental conditions outlined in MIL-E-4970.

Characteristics:

Input: 108-132 volts, 60 cps
Output: adjustable between 27.5 and 28.5 vdc, 5 amp
Regulation: within ½ percent
Ripple: within 1 percent, rms
—Perkin Engineering Corp., El Segundo, Calif.

Circle No. 24 on reply card



HIGH EFFICIENCY

A new line of dc permanent-magnet motors, offering efficiencies as high as 45 percent, satisfies a wide variety of military and commercial applications. Stock models from 4 to 30 vdc are available. A steel shell shields the Indox I field structure. Either sleeve or ball bearings may be specified.—The Reflectone Corp., Stamford, Conn.

Circle No. 25 on reply card

simple

portable

inexpensive

FLIGHT SIMULATION TABLE

Micro Gee Model 10C

is a single-degree-of-freedom roll table designed for small amplitude perturbation studies about null.

Used by many leading aircraft and missile manufacturers for testing gyros, accelerometers and automatic stabilization systems, either statically or dynamically.



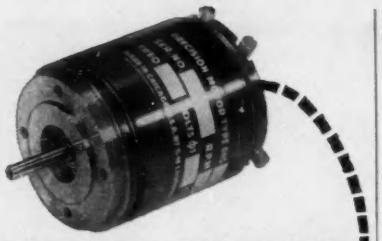
This important tool has a threshold of less than 5 microradians — approximately one second of arc — and is ideal for frequency response and dynamic threshold measurements. It takes loads up to 5 pounds on a 6″x6″ base. Extremely smooth operation is provided by specially-designed, electro-dynamically driven, pendulum mechanism that eliminates the problems created by friction, backlash and use of conventional bearings.

Model 10C is easily used in a closed loop with an analog computer for simulated flight testing of automatic flight control equipment on the ground.

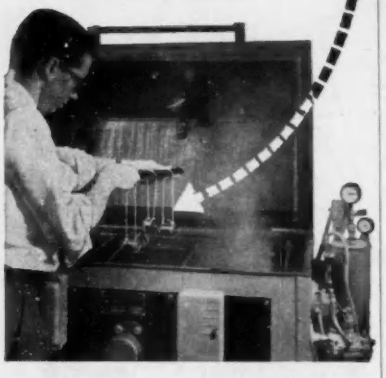
Get complete data on this simple, portable, inexpensive, single-degree-of-freedom roll table that is designed for small perturbation stability studies. Write or phone . . .

New Model 12A Micro Gee Simulation Table takes loads up to 50 pounds on a 12″x12″ base. See it at Wescon, Booth 1709

MICRO GEE PRODUCTS, INC. 6319 W. Slauson Ave., Culver City, California • EXmont 1-1716



STIFF DOSE OF SALT



Exposure . . . to the equivalent of a stiff sea spray . . . on a hot, humid day—one more test the G-M Servos take in stride.

Not just a promise—but a tested fact.

G-M Servo Motors are built to deliver the ultimate in performance. The salt spray test shown above is just one of a battery of tortures designed to prove G-M Servos under all extremes of humidity, temperature, altitude, vibration and salt spray.

At G-M "Designed to Meet Mil. Environmental Specifications" is backed by production testing that does just that!

4 GOOD REASONS WHY G-M SERVO MOTORS SERVE YOU BEST!

1. G-M Servo Motors are available in standard sizes.
2. Standard G-M Servo Motors can also be modified to meet specific requirements.
3. Creative engineering in designing special servo motors with special characteristics.
4. Fast production—better service.



Write Now for information, or send for complete G-M charts and specifications. No obligation, of course.

G-M Servo Motors

manufactured by the Components Division of

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4340 N. Knox Avenue • Chicago 41

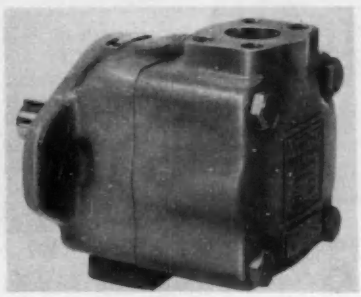
NEW PRODUCTS

PLUS . . .

(26) **General Electric Co.**, Schenectady, N. Y., now makes a 28-volt **transistorized dc power supply** specifically designed for use in computers and laboratory test equipment. . . . (27) Another **tubeless, voltage-regulated supply** by **Kepco Laboratories, Inc.**, Flushing, N. Y., delivers 0 to 36 volts, 0 to 5 amps. . . . (28) **Amplifier Corp. of America**, New York, recently announced a new automatic and manual ac, **variable-voltage power source** that consists basically of a reversible motor-driven Variac and a special double-contact meter relay with interlocked motor drive control relays. . . . (29) **Master Specialties Co.**, Los Angeles, Calif., has a 5½-oz **power supply** that provides 60 ma at 300 vdc from a 115-volt, 400 cycle source.

Circle No. **26, 27, 28,** or **29** on reply card

ACTUATORS & FINAL CONTROL ELEMENTS



HIGH PERFORMANCE

The hydraulic pump shown above is one of a new line of high-performance pumps designed for more power and less space. At 1,200 rpm and 100 psi, the first model of the series delivers 17 gpm, 14 gpm, or 12 gpm from the same package size. Performance of the pump permits a horsepower absorption capacity of up to 36 hp, or more than twice that of earlier pumps of the same size.—Vickers, Inc., Detroit, Mich.

Circle No. **30** on reply card

QUICK RESPONSE

A small, powerful dc motor designed for applications requiring rapid acceleration and variable speed, gains 63



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Please write to: Mr. K. H. Stevenson, Engineering Personnel, North American Aviation, Los Angeles 45, California.

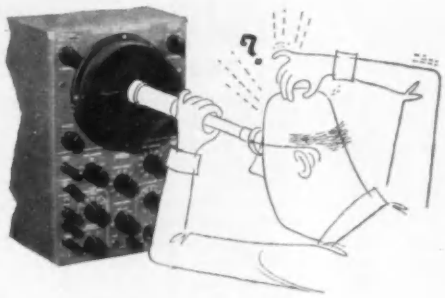
THE LOS ANGELES DIVISION OF

NORTH AMERICAN AVIATION, INC.

JOURNAL OF APPLIED CONTROL DEVICES THAT NEVER WEAR OUT

For Control Engineers Who Are Wearing Out Before Their Time

WHEN A SIGNAL ALMOST ISN'T...



We feel like passing out cigars because our development engineers have given birth to a new addition to the CONTROL standard line of proportioning reactors that never wear out. It's a pre-amplifier that will work from a 200-microwatt signal, with a 3-cycle response. Hitch it to a CONTROL proportioning reactor and in one step you have wide range control of a 2-KVA load. That means if you have to work from the minute output of a small tach-generator, thickness gauge, electronic relay or process control instrumentation, you should write us. *We've got CONTROL pre-amplifier specifications ready for you.*



THE HECK WITH MAINTENANCE!

There are no moving parts in a CONTROL proportioning reactor. There are no filaments to burn out. There are no adjustments to make. You can bury them, fly them through the troposphere, or install them in the corrosive atmosphere of a chlorine plant—it makes no difference. If you're tired of control equipment that has to be pampered with maintenance, you're for us. Servicing? Parts replacement? No more, friend, no more. We're better than hormones for the pooped-out control engineer. *Why not write us your troubles?*

DESIGN CONTROL CIRCUITS WITH BUILDING BLOCKS...

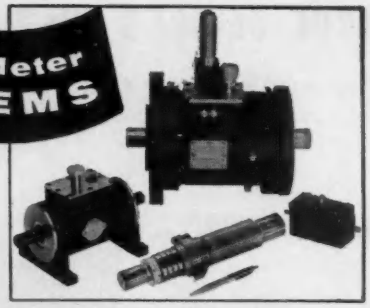


When we took "never wear out" magnetic devices into the industrial control field, we made the grand plunge—designed standard lines which a systems engineer could design into his equipment right from the CONTROL catalog. That put an end to the high price of the unusual advantages of saturable reactors. Instead of custom designing, we mass produce—and your costs come tumbling down. *Want to select the building blocks to design your control circuits? We have information on CONTROL'S standard proportioning reactors—theory, characteristics, typical uses. It awaits your letter.*

Reliability begins with CONTROL

A DIVISION OF MAGNETICS, INC.

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Torque Meter SYSTEMS

designed to meet your specific needs

B & F offers the only complete line of Torquometers and Indicators with individual models designed to satisfy specific industrial Torque measuring requirements. Principal of operation is basic, easily incorporated into rugged housings capable of continuous high speed industrial applications. Quality high-signal transducers provide accurate linear readings with negligible hysteresis in high speed and variable temperature operations.

Standard models cover ranges from 0.5 in. oz. full scale through 30,000 in. lb. full scale. Torquometers are available with foot mounted housings and AND-type housings with splined shaft-ends for use on pump test stands and for testing engine accessories. These models are designed to mate with and support pumps, generators, starters, etc. and can be air-purged and pressurized for use in hazardous atmospheres.

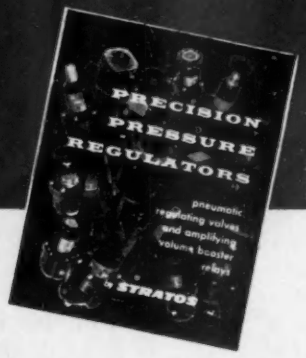
NEW miniature Models "D" and "E" cover the in. oz. and low in. lb. ranges required to evaluate servo motors and other low inertia systems.

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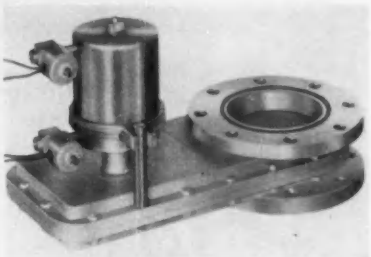
NEW PRODUCTS

percent of its rated speed of 5,500 rpm in 0.014 sec, from a standstill. Suitable for most servo systems and operable in any position, it will handle frequent starts, stops, and reversals as well as widely varying loads.

Characteristics:

Rated voltage: 200 vdc
Rated speed: 5,500 rpm
Power output: 2.2 hp
Frame size: 5.16 in. diam, 15.5 in. long
Stalled torque: 10 lb-ft
—General Electric Co., Schenectady, N. Y.

Circle No. 31 on reply card



LINEAR-TO-ROTARY MOTION

This new remote control device, shown mounted on a high-vacuum gate valve, converts linear motion of a guided plunger into 180 deg of shaft rotation. The plunger operates within a double-acting pneumatic cylinder by turning a spirally fluted shaft. Solenoid valves, which direct nominal plant air pressure to either side of the plunger, may be mounted adjacent to the cylinder, as shown in the photo, or remotely located. Where desired, manually-operated air valves may be used in place of the solenoids.—Vacuum Research Co., San Francisco, Calif.

Circle No. 32 on reply card

PLUS . . .

(33) **Slanner Electric Valve Div.**, New Britain, Conn., now offers a new line of **three-way solenoid valves** for use with medium-size cylinders. . . . (34) A screw-in type of **dimple motor explosive actuator** has been added to the product line of **Holex, Inc.**, Hollister, Calif. . . . (35) **Automatic Switch Co.**, Florham Park, N. J., now makes a heavy-duty, **solenoid-controlled cylinder** in two sizes capable of handling either 360 lb at 50 psi or 375 lb at 150 psi. . . . (36) Three new **internal locking hydraulic cylinders**, by **Tog-Loc**,

NEW

LOW NOISE *
MINIATURE CHOPPERS
by AIRPAX

AIRPAX has developed a new series of miniature choppers characterized by extremely **low noise*** level for use in null seeking servo systems, instrument amplifiers, and similar applications.

Series 2300 choppers operate from a 6.3 VOLT 400 CPS source. Permanently adjusted contacts and AIRPAX armature design insure long life — over 5000 operational hours!

Drive coil leads are brought to top terminals minimizing drive and contact circuit coupling. Choppers are hermetically sealed for operation in any atmosphere.

Although designed for dry or nearly dry circuits **surges of 2 milliamperes at 100 volts do not change operational characteristics!**

Normal operating temperature range is — 65C to + 100C. Extended temperature range choppers and variations of top terminal connectors and base headers, are also available from stock.

- ✓ Dependable
- ✓ Long Life
- ✓ Low Cost
- ✓ Available from stock

* Sub-micro-volt region

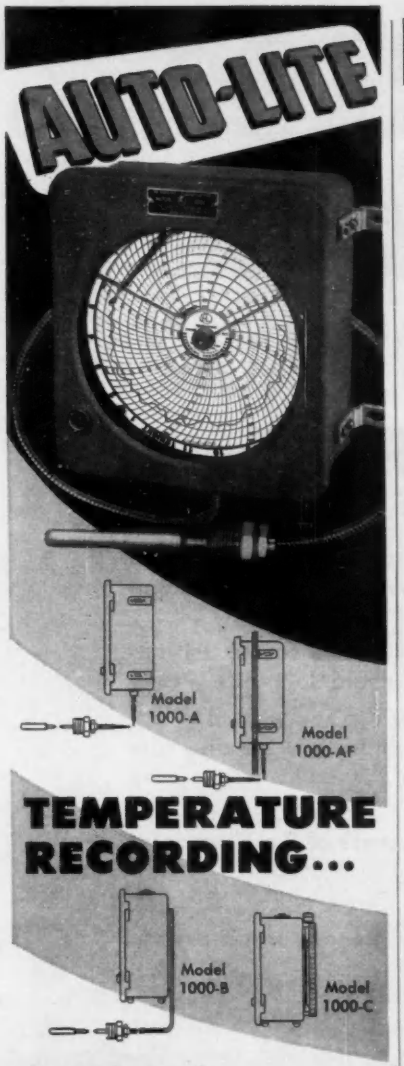
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SERIES 2300 FOR 400 CPS

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Charts the truth about Temperature

Auto-Lite model "1000" Recorder has capillary tubing for remote reading, easily observed 6" chart . . . Various standard ranges from minus 40°F to plus 550°F . . . Wall mounting, portable or portable self-contained types . . . Electric or mechanical chart drive . . . 24-hr. or 7-day cycle . . . Priced as low as $49.50.

NEW! Auto-Lite TRANSISTORIZED Recorder, Model "2200" . . . charts temperature cycles without the use of ink. Priced from $73.

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TEMPERATURE RECORDERS AND INDICATORS

NEW PRODUCTS

Inc., Bellevue, Wash., operate on pressures up to 1,500 psi and can be locked in either the retracted or extended positions.

Circle No. 33, 34, 35, or 36 on reply card

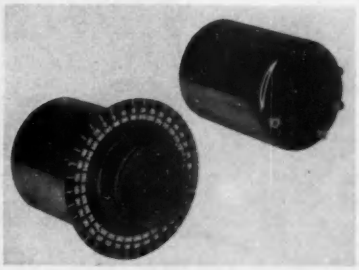
RESEARCH, TEST & DEVELOPMENT



ISOLATION AMPLIFIER

The Model 202 differential or isolation amplifier is designed for an oscilloscope or voltmeter measuring ac voltages whose reference is not at ground potential, as is the case in servo systems, magnetic amplifiers, ac bridges, and circuits using floating power supplies. Frequency response is plus or minus ½ db between 300 cps and 100 kc, and 3 db down at 30 cps and 1 megacycle. Phase shift at 60 cycles is less than 5 deg. Output is rated nominally at 50 ohms isolated from ground, with a 1 volt peak-to-peak maximum output.—Quan-Tech Laboratories, Morristown, N. J.

Circle No. 37 on reply card



LOW ERROR BRIDGE

Introducing an error of less than 8 sec of arc, the Model SB-12 miniaturized synchro bridge measures the angular position of ac servo systems as well as

digital computer research

A quiet revolution is occurring in the field of real-time computing and control systems. The Hughes Digitair computer has already successfully invaded this one-time analog domain. The accelerating pace in smaller, lower power circuit-elements is rapidly widening the digital margin of superiority. An important part of the advancement in the digital control art is occurring in the Airborne Systems Laboratories at Hughes. There engineers are working in every phase of this exciting field. The comprehensive and balanced program includes:

- Research in vacuum-coating of entire printed circuits
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ANOTHER NEW LESLIE PRODUCT

ADJUSTABLE PROPORTIONAL BAND Floatless LIQUID LEVEL CONTROL

...with adjustable level ranges up to 0-200"

Here is a new differential pressure-type liquid level control pilot that combines the wide adjustable level ranges in the table shown below with a 2-20" or 7-25" adjustable proportional band.

ADJUSTABLE LEVEL RANGE — INCHES	ADJUSTABLE PROPORTIONAL BAND (INCHES, H_2O)	CONTROL PILOT TYPE
0-40 or 0-87	2-20	LAP
0-30 or 0-91	2-20	LABP
0-200	7-25	LAUP

Maximum Static Pressure — 300 psi

One Knob — Easy Adjustment

A single knob adjustment quickly sets the proportional band where you want it, even while the system is in operation. The liquid level is maintained constantly within that band until you re-set the control pilot for new conditions.

Applications

Leslie-Level-Matic Control Pilots are used in either open or pressurized vessels to control the level of virtually any liquid including water, gasoline, oil and chemical solutions. The new control pilot is particularly useful to maintain constant levels where there are high flow rates through vessels with small cross sectional areas.

Float Cages Eliminated

There are no floats or cages needed for Leslie-Level-Matic Control Pilots, and no torque tube seals, stuffing boxes, or thermohydraulic systems. All of the primary control elements are in one place and may be installed with a fraction of the effort and cost required for displacement-type controllers.

Vibration-Proof, Dependable

All of the dependability factors for which Leslie products are so well-known are incorporated in this new control pilot, as well. Rugged, accurate, stable — it is unaffected by normal vibration or turbulence.

More Information

Send for Engineering Data Sheet describing this new Control Pilot and outlining its principle of operation.

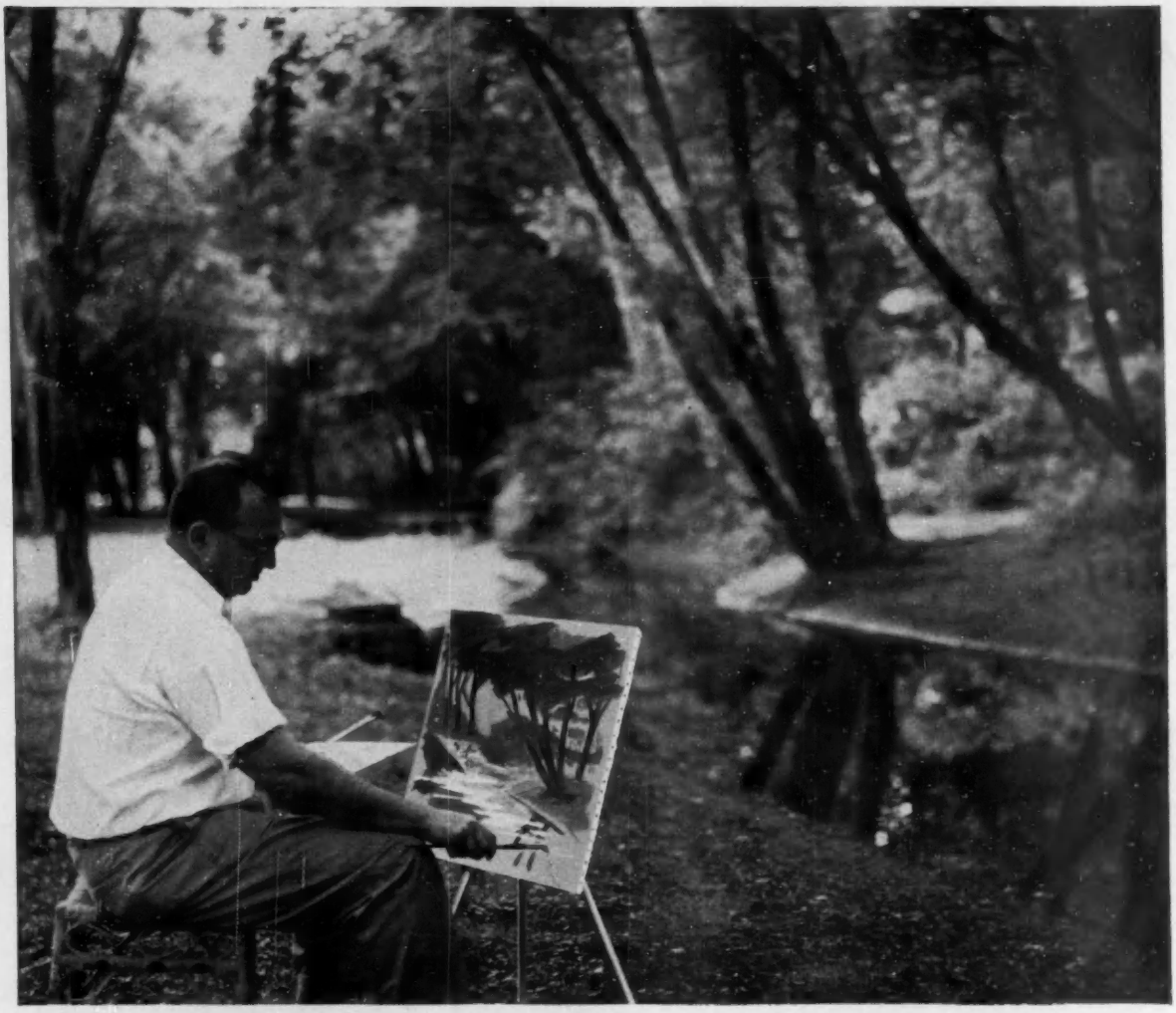


Knob and indicator-type proportional band adjustment permits setting in a matter of seconds.

LESLIE **REGULATORS and CONTROLLERS**

674

LESLIE CO., 211 Grant Avenue, Lyndhurst, New Jersey



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Painting pictures, designing missile systems... creativity typifies the General Mills engineer



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CONTROL ENGINEERING
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(100) PRESSURE TRANSMITTER. International Resistance Co., Bulletin R-1b, 4 pp. Photos, circuit diagrams, and specifications describe a new line of pneumatic pressure pickups for indicating, recording, or control applications.

(101) TORQUE MOTORS. Peerless Electric Co. Bulletin T-1. Covers this company's complete line of torque motors, discussing ratings, frame sizes, special models, and general application.

(102) TRANSISTORIZED CONVERTER. Fischer & Porter Co. Bulletin 50DC1000, 2 pp. Provides a brief description of a new transistorized analog-to-digital converter. Headings cover inputs, outputs, display, performance data, operation, characterization, and chassis.

(103) STRIP-CHART RECORDER. Varian Associates. Data Sheet G-11A, 4 pp. Discusses operation, specifications, and optional features of a new portable panel-mounted strip-chart recorder of the null-balance potentiometer type.

(104) HIGH-SPEED PUMPS. Vickers, Inc. Bulletin M5108, 4 pp. Features typical performance curves on a new line of high-performance balanced vane pumps, which operate at speeds up to 2,000 rpm and pressures to 2,000 psi.

(105) CYLINDER CATALOG. Petch Mfg. Co. Catalog No. PMC58. Includes engineering data and complete specifications on a new line of "Power Master" air and low-pressure hydraulic cylinders. Sizes range from 1½ to 6 in. in 11 standard mounting types.

(106) RESISTANCE BOXES. Cinema Engineering. Catalog 20D, 8 pp. Decade boxes of two basic designs are covered, offering both horizontal and vertical panel arrangements. All use aluminum alloy panels and gray walnut boxes.

(107) RESTRICTOR VALVE. Fluid Controls, Inc. Catalog sheet. Provides specifications on a unique restrictor valve that features a safety retention cap to prevent complete removal of the needle and blow-out of the stem.

(108) SPECTROPHOTOMETER. Perkin-Elmer Corp. Brochure, 24 pp. Describes what infrared is and how it is used for the identification of unknowns, for qualitative and quantitative analysis, for product control, and as a permanent step-by-step record of a chemist's work. Design specifications and performance of the Infracord are thoroughly described.

(109) PRESSURE-VACUUM CONTROLS. United Electric Controls Co. Condensed catalog 500, 8 pp. Furnishes an unusual number of specifications in addition to other data. Text describes a wide variety of pressure-vacuum controls, features general-purpose, sensitive, extremely sensitive, dual switch differential, absolute and explosion-proof units.

(110) RECORDING ANNUNCIATOR. Panellit, Inc. Bulletin 102, 4 pp. Illustrates the advantages of a new, recording-type annunciator for producing a permanent record of off-normal and on-off operations. Drawing shows a typical length of record as produced on low-cost, adding-machine tape.

(111) ANALOG COMPUTER. Electronic Associates, Inc. Brochure, 4 pp. Briefly describes features of the new Pace 231R analog computer. Two-page photo shows typical system fully expanded.

(112) ELECTROMECHANICAL TERMS. Hoover Electric Co. Interesting and informative "Glossary of Electro-Mechanical Terms" includes useful form-

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ulas and design data sheets helpful to design and purchasing people in the aircraft missile, ordnance, electronic, ground support, and industrial control fields.

(113) THERMISTOR APPLICATIONS. Fenwal Electronics, Inc. Catalog EMC-2, 16 pp. Provides 15 typical application circuits using thermistor elements. Product specifications cover nearly 400 different types. Resistance-temperature tables for different materials are also included.

(114) PURGE-METER SPECS. Fischer & Porter Co. Spec sheet 10A3135, 2 pp. Reviews construction, design, performance and operational limits of a purge meter featuring a snap-in meter tube. Dimensional drawings, sectional view included.

(115) DATA PROCESSING. Taller & Cooper, Inc. Literature includes a four-page folder and five application sheets. Folder describes and illustrates the operation of the company's business data processor, and sheets offer suggestions for commercial applications.

(116) TEMPERATURE CONTROLLER. Fenwal, Inc. Brochure MC-168, 4 pp. Shows how simplified mechanical design of a new indicating controller offers advantages in installation, maintenance, adjustment, accuracy, and flexibility. Also describes housing styles, temperature ranges, and switching mechanisms.

(117) MINIATURE LIGHTS. Eldema Corp. Bulletin, 4 pp. Photos illustrate a wide variety of miniature neon and incandescent indicator lights for both military and commercial applications. Sectional drawing of a typical neon unit provides information on construction and operation.

(118) DIFFERENTIAL TRANSFORMER. International Resistance Co. Bulletin R-3a, 4 pp. Provides general specifications and discusses the electrical characteristics and construction of the Series 70-3000 Compu-tran Displacement Transducer. Tables give dimensions of both standard and miniature models.

(119) FEEDING SYSTEMS NOMOGRAPH. Milton Roy Co. Folder, 4 pp. Handy nomograph enables process engineers to quickly determine pump capacities and holding tank sizes for metering applications. First page explains its use, solves a typical problem.

(120) CONSTANT-SPEED DRIVE. Lycoming Div. of Avco Mfg. Corp. Brochure, 4 pp. Describes a 20-kva constant-output-speed drive for aircraft (400-cycle) power systems. Curves illustrate transmission efficiency, response at various speeds.

(121) BULK-LEVEL CONTROL. Bin-Dicator Co. Consolidated catalog covers three products for the indication and control of level in bulk material storage and handling equipment. Includes specifications, photos, cutaway and schematic drawings, and application information.

(122) WASTE TREATMENT. Milton Roy Co. Application engineering data sheet D-58-1, 4 pp. Describes the application of controlled-volume metering equipment to continuous cyanide- and chrome-waste treatment systems. Schematics illustrate the processes.

(123) POLARGRAPHIC ANALYSIS. Leeds & Northrup Co. Data Sheet E-94(3), 4 pp. Reviews important design features of the Electro-Chemograph, an analysis instrument that makes use of the polargraphic principle of operation. A typical recording is shown and described.

(124) AIRBORNE ELECTRICAL SYSTEM. General Electric Co. Bulletin GET-2743, 8 pp. Describes GE's new 10 kva aircraft and missile electrical system, giving details on operation, mechanical design, electrical performance, and system advantages.

(125) CLUTCHES AND BRAKES. Autotronics, Inc. Catalog 957, 48 pp. Covers a complete line of miniature and subminiature electromagnetic clutches and brakes. Information includes cutaway drawings, engineering data, schematic diagrams, dimensional data, minimum performance curves, and other details.

(126) HYDRAULIC CYLINDERS. Teer, Wickwire & Co. Bulletin H-101, 8 pp. Lists 23 construction points in the company's "H"-Line of 2,000-psi hydraulic cylinders. Tables of developed forces and physical characteristics are included.

(127) ORIFICE METER. George Kent, Ltd. Publication 276, 2 pp. Introduces the Dall Orifice, a new differential pressure meter for measuring flow of water, compressed air, low-pressure air, noncorrosive gases, and low-pressure steam. Other data covers installation and specifications.

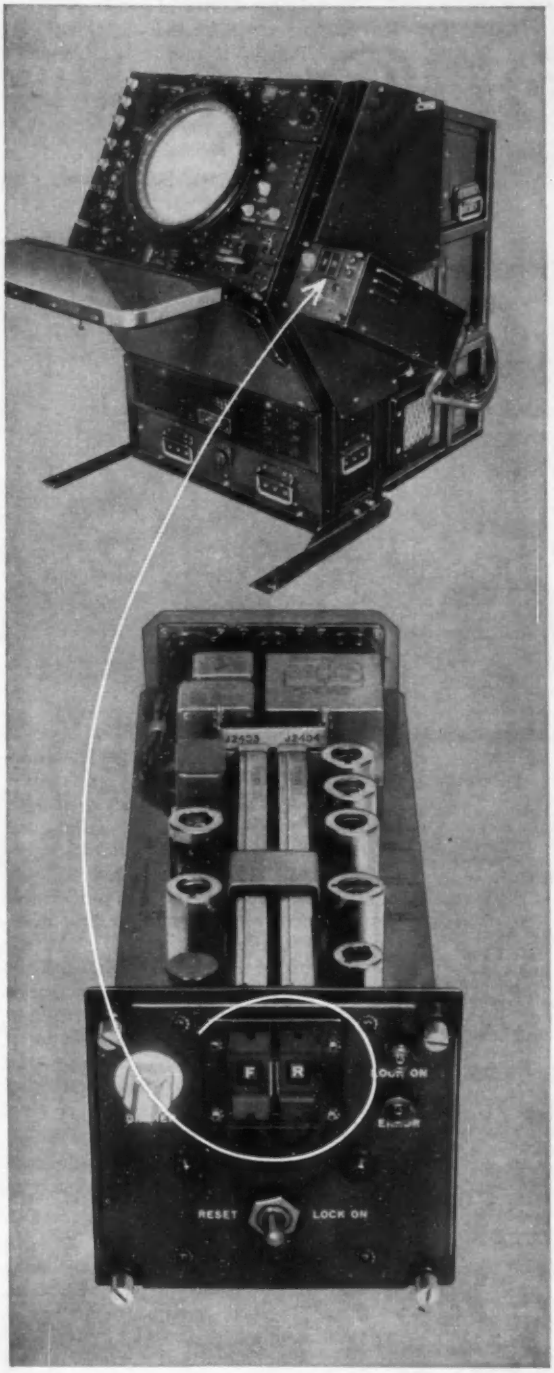
(128) DEW-POINT METER. Illinois Testing Laboratories, Inc. Bulletin No. 2051, 8 pp. Fully describes the Alnor Dewpointer, which uses varying pressure rather than temperature to determine dew points of any given gas sample.

(129) VOLTAGE REGULATOR. Sorensen & Co. Product Data Sheet, 2 pp. Points out principal features of a new universal ac voltage regulator, Model APR-1010. Lists both electrical and physical characteristics.

(130) FEEDWATER REGULATOR. Blaw-Knox Co. Bulletin 1045, 4 pp. Explains, through a schematic diagram, the operation and application of the company's Flowmatic direct-operated feedwater regulator. Lists specs on the thermostatic tube and regulating valve.

(131) HIGH-SPEED PRINTER. Stromberg-Carlson Div. of General Dynamics Corp., Brochure, 12 pp. A technical description of the SC-5000 high-speed electronic printer is given in six sections. Of particular interest is Section II, which describes the use of the Charactron shaped-beam tube in conjunction with the Xerox high-speed dry printer.

Union Indicators help Hazeltine radar-display unit identify aircraft



Just a glance at the little black box on the right side of this radar-display unit tells the operator whether an approaching aircraft is friend or foe. The IFF response is processed by radar equipment and is displayed in the Hazeltine unit by Alpha-Numerical Indicators manufactured by Union Switch & Signal. The radar-display unit is manufactured by Hazeltine Electronics Division of Hazeltine Corporation, Little Neck, New York. Hazeltine chose Union Switch & Signal's Alpha-Numerical Indicators because of their compact design and supreme reliability, and for the features listed below.

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NEW PRODUCTS

the electrical error of synchros and resolvers. One-fifth the volume of previous models, it readily lends itself to panel mounting. The 4-in. dial has a 360-deg range. Line-to-line resistance is 10 k.—Theta Instrument Corp., East Paterson, N. J.

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HIGH LOAD CAPACITY

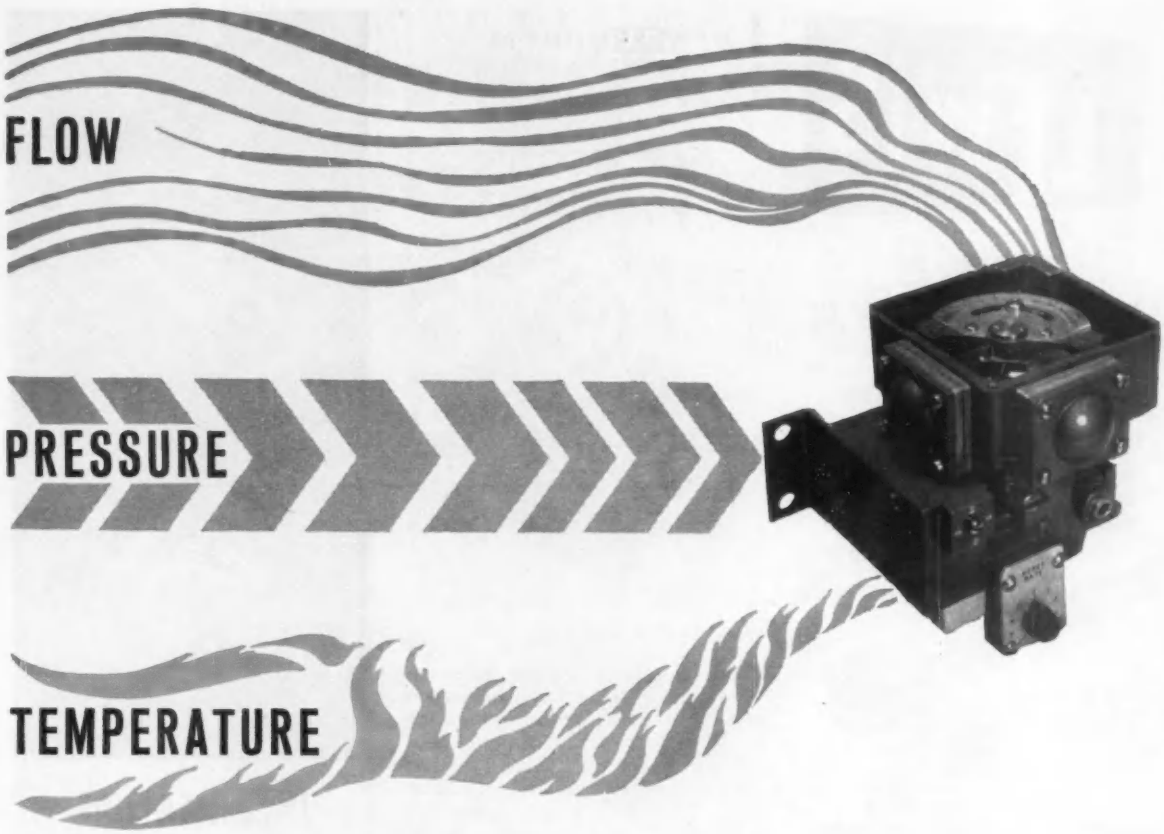
Photo shows the Model 12A Simulation Table, a single-degree-of-freedom roll table for angularly displacing gyros, accelerometers, and small guidance packages, either statically or dynamically. Features include a larger load capability than earlier models and a special drive mechanism that minimizes friction and backlash. Its big capacity permits it to simulate a flight test on one axis of a complete aircraft or missile stabilization system, following signals from an analog computer, low-frequency function generator, tape recorder, or digital-to-analog converter. —Micro Gee Products, Inc., Culver City, Calif.

Circle No. 39 on reply card

PLUS . . .

(40) **Presin Co.**, Los Angeles, Calif., has announced the Model KM-1 **Short Time Interval Meter**, which has a measuring range, in eight steps, of from 5 microsec to 1 sec and an accuracy within 2 percent. . . . (41) The Type 401-A **low-frequency oscilloscope**, by **Allen B. Du Mont Laboratories, Inc.**, Clifton, N. J., features front-panel amplifier controls and sweeps as slow as 2½ sec, full scale.

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Control Any Process Variable

with a system based on

REPUBLIC'S NEW TYPE "VC" PNEUMATIC CONTROLLER

Here is an all purpose null-balance-vector controller for use with any pneumatic transmitter. Its proportional band ranges from 2% to 500% *without changing parts*, for quick adaptation to changes in process requirements. Especially important in high-precision control, Republic's Type VC has exceptional sensitivity and a narrow dead band (less than 0.05%). Its high capacity non-bleed pneumatic amplifier consumes little air, keeps output ample. A selector block permits reverse or direct action. Local or remote pneumatic set point optional.

Companion instruments—using an identical null-balance-vector "heart"—include differential pressure, temperature and pressure transmitters . . . ratio, totalizing, multiplying, squaring and square - root - extracting relays. Many parts are interchangeable among the instruments in this "family". Besides reducing spare parts inventory, the similarity of components simplifies the task of training personnel.

Let a Republic engineer show you how these instruments can help to achieve accurate, efficient, dependable control systems. Republic Sales Offices are located in principal cities throughout the U.S.A. and Canada.

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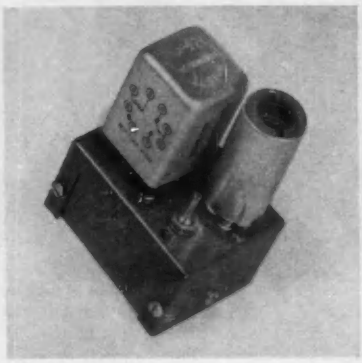
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NEW PRODUCTS

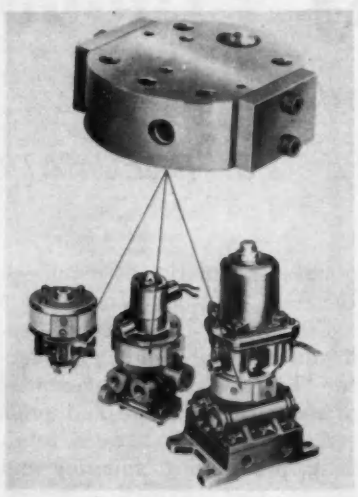
ACCESSORIES & MATERIALS



INDICATES FAILURE

Called a Channel Failure Indicator, this device monitors a communication circuit for failures or temporary interruptions. If the circuit or power fails, a relay becomes de-energized and sets off an alarm or lights an indicating lamp. Units are designed to plug into a Model 912 or 995 receiver.—Radio Frequency Laboratories, Inc., Boonton, N. J.

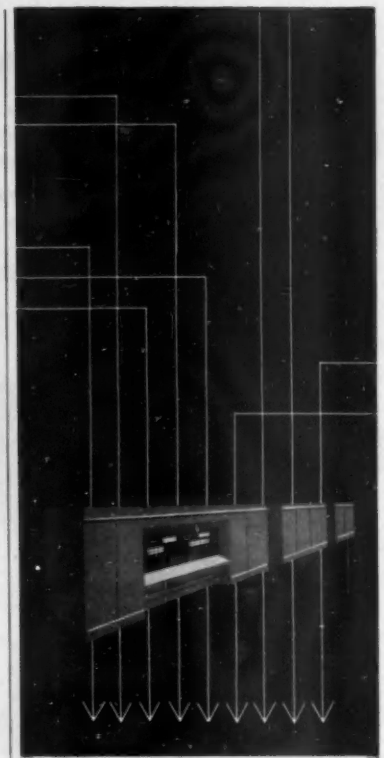
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AIR VALVE CONVERTER

Photo shows how a new double-stroke adapter can be inserted into any of the company's Skyline series air valves to provide momentary action.—Ross Operating Valve Co., Detroit, Mich.

Circle No. **43** on reply card



INFORMATION SEARCHING and RETRIEVAL

A new and major program at The Ramo-Wooldridge Corporation is devoted to the design and development of a large-scale system for the automatic handling of reconnaissance information. The basic systems problems include the handling of ordinary language on computers and the design of automatic searching and retrieval techniques.

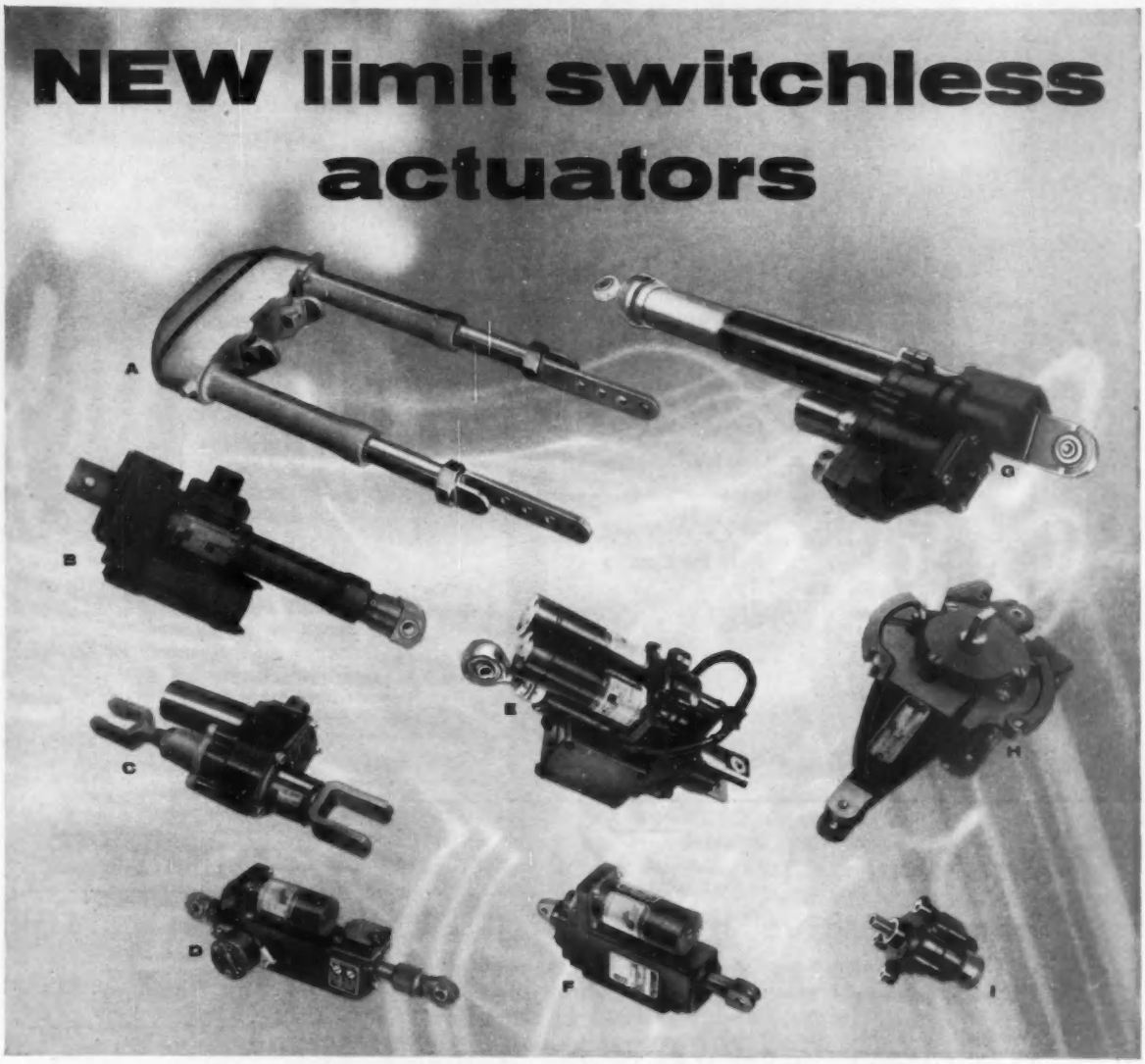
Inquiries are invited from electrical engineers, mathematicians and physicists whose backgrounds include operations research analysis and systems analysis of digital computing equipment.

For additional information, write to **Mr. Leslie Levin.**

The Ramo-Wooldridge Corporation

P. O. BOX 45215, AIRPORT STATION
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NEW limit switchless actuators



Reduce weight and cost 25% below conventional design

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Elimination of limit switches in power actuators is a result of AiResearch development of superior high temperature motors and resilient non-jamming positive stops.

Limit switches are eliminated by two methods: 1) use of continuous stall high temperature motors, 2) use of high temperature motors with thermal protectors which permit maximum *on* time in the duty cycle.

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Development of Limit Switchless Actuators reflects AiResearch experience in producing more than a million rotary and linear units. Current production includes several hundred actuator types, many with high temperature applications.

Your inquiries are invited.

- **A** *Seat Actuator, CONVAIR B-58*
- **B** *Seat Actuator, LOCKHEED F-104*
- **C** *Rotor Blade Trim Actuator*
- **D** *Elevator Actuator, TEMCO XKDT-1 Target*
- **E** *2-Motor Trim Actuator, REPUBLIC F-105*
- **F** *General Purpose Linear Actuator*
- **G** *Dual Purpose Feel Trim Actuator, AVRO CF-105*
- **H** *Rudder Trim, AVRO CF-105*
- **I** *Duct Shutter Actuator, LOCKHEED ELECTRA*

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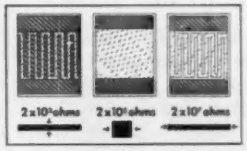




This is a photosensitive resistor... actual size

It's called a Kodak Ektron Detector, the photosensitive substance is lead sulfide, and it can be laid down in any pattern.

- Signal response extends from 0.25 microns in the ultraviolet to 3.5 microns in the infrared with maximum sensitivity at 2.2 microns in the infrared.
- They are available in complex and exact arrays and mosaics.



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- Vibration doesn't affect them.
- Elements can be extremely small in size.

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Kodak

ABSTRACTS

Batch Process Control—II

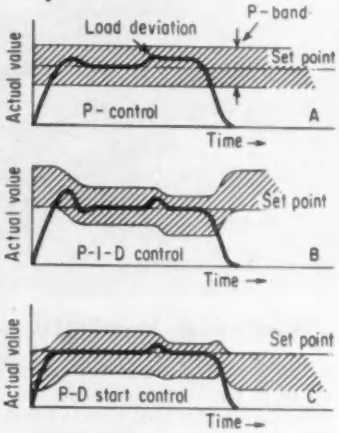
From "Automation of Batch Processes; Problems Involved and Their Solution Relative to the Use of Equipment", by H. Sartorius and H. Kaltenecker, an article in the German publication REGELUNGSTECHNIK, Vol. 6, No. 2, 1958. The second of three abstracts prepared by Sigmund Rappaport, project supervisor at Ford Instrument Co. and adjunct professor of kinematics, Brooklyn Polytechnic Institute.

Starting problems

To make a batch process economical, desired temperatures should be reached as fast as possible—but without overshoot. The following considerations are based on pneumatic control theory, but are generally applicable to other modes. The letter P stands for proportional action, I for reset or integral, and D for derivative or rate action.

Figure 1A shows a graph of actual value vs. time when a P control is

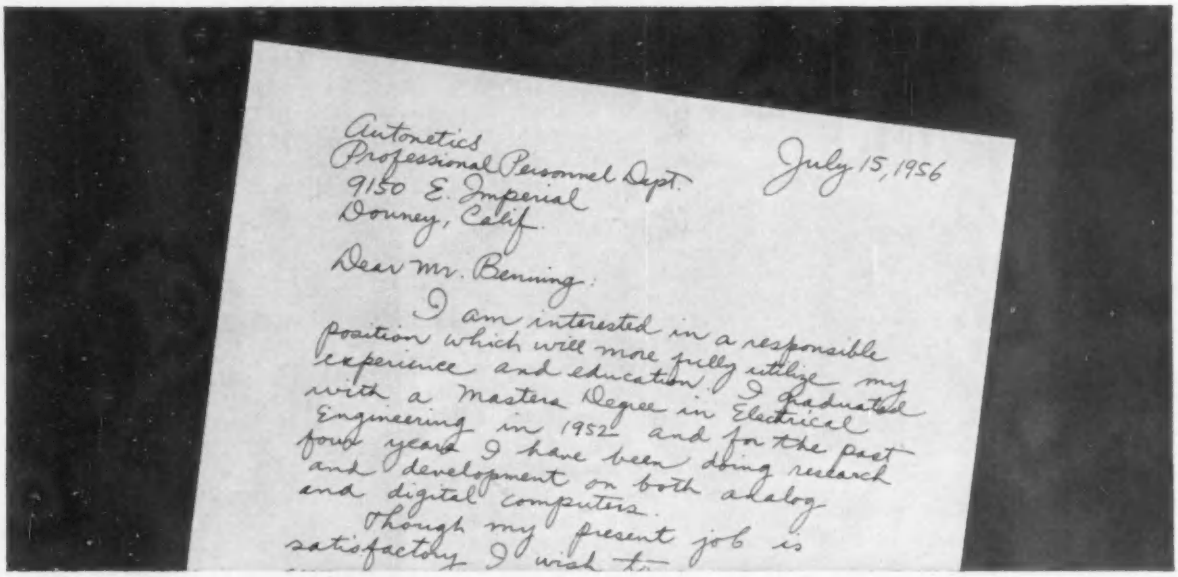
Fig.1



used. Any load disturbance causes a permanent offset. The alternatives are $P - I$ and $P - I - D$ control; but, as Figure 1B shows, the normal $P - I - D$ control, although not influenced by a load disturbance, has a high initial overshoot.

The good starting characteristics of the $P - D$ control and the good operating characteristics of the $P - I - D$ control can be combined by starting with the $P - D$ behavior pattern and switching over to $P - I - D$ behavior when the proportional band is reached. Figure 1C shows the performance of such a system. Pneumatic relays do the switching.

This result can also be achieved



This letter moved an engineer ahead 5 years

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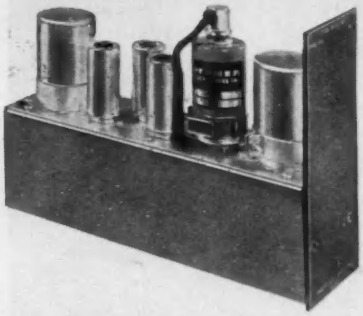
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THE OFFNER TYPE 190

DIFFERENTIAL DATA AMPLIFIER

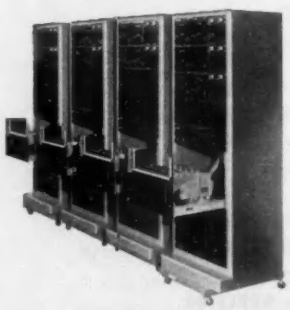


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Zero-drift d-c recorder with microvolt sensitivity. One amplifier type covers all requirements.
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(After August 15, 1958)

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ABSTRACTS

with a $P - I$ control whose D effect is utilized in the measuring arm of the circuit rather than in the feedback.

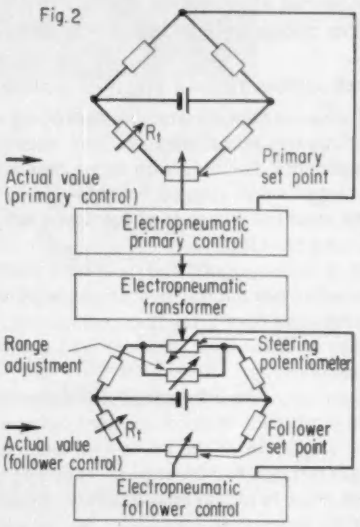
Overshoot can also be handled in various ways. One is to manually set the control below the desired value and gradually raise it later. This technique, however, calls for appreciable experience. The best approach seems to be to use a programming device; it achieves the settings for the desired values in such a way that the control remains automatically within preset limits.

Control of batch processes

The main difficulty in batch process control is in the exacting requirements for close temperature control. The large time constants compound this problem.

Direct control, with one regulator only, seldom satisfies these requirements, and cascade control becomes necessary. Figure 2 shows the instrumentation for cascade control of the

Fig. 2



temperature in an autoclave. The primary circuit contains the sensing element, located in the autoclave. Its output adjusts the setting value of the follower control, which regulates the temperature of the steam jacket. Since the time constant of the latter is always much smaller than the time constant of the autoclave, all deviations are smoothed out much faster. Such cascade control is easily stabilized if the ratios of the time constants are at least 1:5.

In the schematic shown, the first electropneumatic control device (command control) compares the actual value on the resistance thermometer

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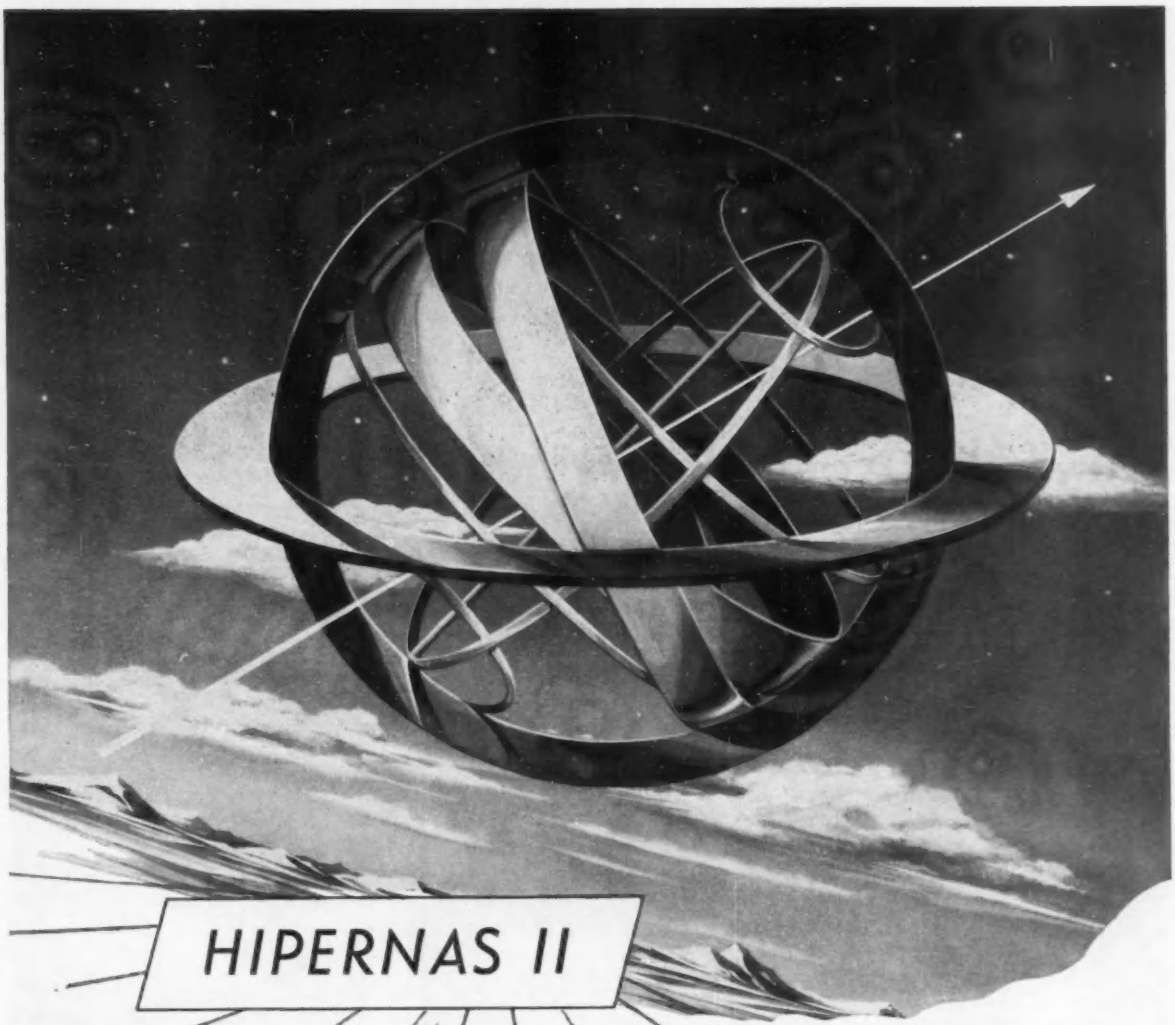
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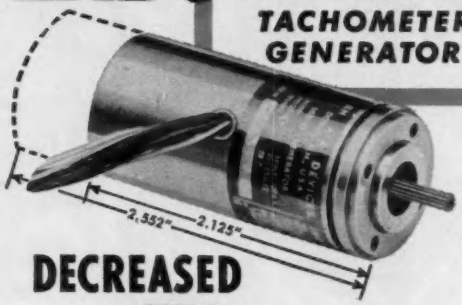
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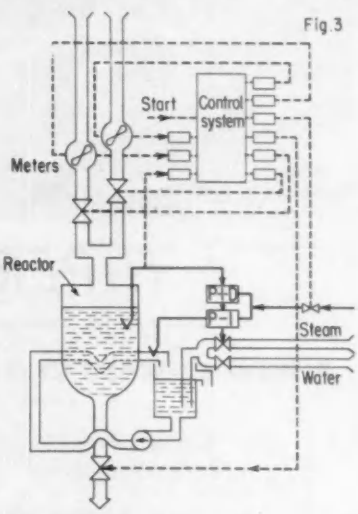
ABSTRACTS

in the autoclave with the desired valve. The output signal is transmitted to the second, or follower control, and there it changes the set-point of the desired value. The follower control, a bridge circuit, compares the actual value with the modified desired value. The permissible range of this modification is set by means of a resistor parallel to the command potentiometer. The follower control governs the steam-jacket temperature.

The control system converts the input values by means of relays, magnetic amplifiers, and transistors. The last have the special advantage of operating without moving contacts. The circuit also contains counters, storage units, and timers. The output devices transform the electrical signals to suit the control links (motors, magnetic valves, pneumatic valves, etc.).

Figure 3 shows a block diagram of a simplified, fully automatic auto-

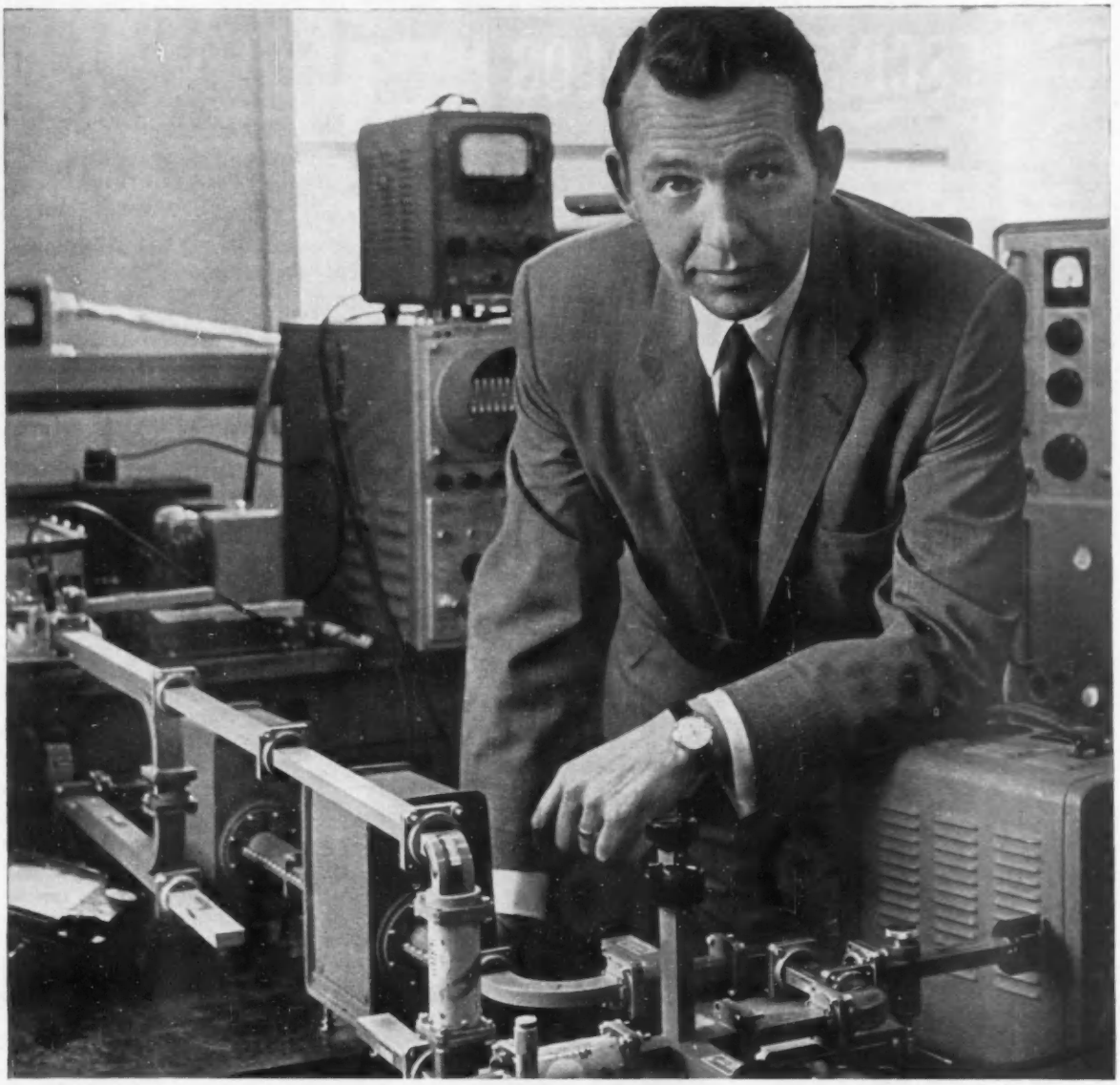
Fig. 3



clave control system. After the starting signal is given, the tank is charged with a predetermined amount of raw material. When the charge is completed, the inlet valves are closed and air is admitted to the pneumatic controls. After the desired value is reached, a counting and timing cycle starts. When this terminates, the operations cease, the outlet valve is opened, and the cycle repeated.

Although methods for start and control of batch processes are fairly common today, fully automatic control is still not used to any great extent. Close cooperation between manufacturer and instrumentation engineer could change this picture in the future.

Sigmund Rappaport



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AUTOMATION SYSTEMS. *Proceedings of the Second EIA Conference on Automation Systems for Business & Industry, sponsored by the Engineering Dept. of Electronic Industries Association.* 180 pp. *Published by Engineering Publishers, New York.* 1958. $5.

This book contains 18 papers delivered at the six sessions of the abovementioned conference. The first two sessions covered automation within the electronics industry, the next two automation in the office and in manufacturing industries outside the electronics field. Session 5 covered the human aspects of automation. In the last session, keynoter Joseph Harrington, Jr. summed up the conference.

Switching-Circuit Theory

SWITCHING CIRCUITS AND LOGICAL DESIGN. *Samuel H. Caldwell, Professor of Electrical Engineering, MIT.* 686 pp. *Published by John Wiley & Sons, Inc., New York.* 1958. $14.

Based on a two-semester course presented by the author at MIT, this book opens with a brief introduction to the properties and general applications of switching circuits, follows this with a most useful chapter on switching algebra. The first part of this chapter establishes switching algebra as an independent structure of ideas. The author intentionally avoids any association with physical components, with the result that the reader is prevented from getting too narrow a view. The second half of the chapter presents an interpretation of switching algebra in terms of simple relay contact configurations and prepares the reader for a restatement of many of the algebra theorems in terms of the contact-network transformations which they describe.

Chapters 4 through 8, and Chapter 11 discuss combinatorial switching circuits in terms of relay contact networks. Chapter 9 covers the use of electronic and solid-state devices in network synthesis. The switching aspects of decimal-binary and cyclic codes are discussed in Chapter 10, along with code conversion and error detection. Three other chapters develop methods of synthesizing sequential circuits with both contact networks and electronic components. Chapter 15, a discussion of pulsed sequential circuits, concludes the book.

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What the Control Engineer Should Know About Reliability, April 1958, 8 pp. Not intended as a comprehensive treatise, but rather as a guide to aim the control engineer in the right direction, this staff-written article discusses the new concept of systems effectiveness, and briefly covers techniques for measuring reliability, predicting reliability, improving reliability, and costing reliability. Up to date reference sources are listed. 20 cents.

Survey of Numerically-Controlled Point-to-Point Positioning Systems, 72 pp. This complete series covers 31 domestic and foreign systems. Detailed operational and performance characteristics of each system are discussed. Individual parts of series are also available as listed below. $1.25.

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Survey of Numerically-Controlled Point-to-Point Positioning Systems—II, February 1958, 24 pp. Includes detailed descriptions of ten machine tool control systems. 50 cents.

Survey of Numerically-Controlled Point-to-Point Positioning Systems—I, January 1958, 32 pp. Includes detailed descriptions of twelve machine tool control systems. 60 cents.

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American Institute of Electrical Engineers, 1958 Special Technical Conference on Nonlinear Magnetics and Magnetic Amplifiers, Hotel Statler, Los Angeles Aug. 6-8

WESCON, sponsored by IRE and West Coast Electronic Manufacturers Association, Pan Pacific Auditorium and Ambassador Hotel, Los Angeles Aug. 19-22

American Institute of Electrical Engineers, Pacific General Meeting, Sacramento, Calif. Aug. 19-22

SEPTEMBER

Association Internationale Pour Le Calcul Analogue, Second International Analog Computation Meeting, Strasbourg, France Sept. 1-9

International Association for Cybernetics, Second International Congress on Cybernetics, Namur, Belgium Sept. 3-10

American Institute of Electrical Engineers, Power Industry Computer Application Conference, King Edward Hotel, Toronto Sept. 15-17

Instrument Society of America, Instrument-Automation Conference and Exhibit, Convention Hall, Philadelphia, Pa. Sept. 15-19

Association of Iron & Steel Engineers, 1958 Iron & Steel Exposition & Convention, Cleveland Auditorium, Cleveland, Ohio Sept. 23-26

Institute of Radio Engineers, Seventh Annual Symposium on Industrial Electronics, Rackham Memorial Auditorium, Detroit, Mich. Sept. 24-25

OCTOBER

National Electronics Conference, sponsored by IRE, AIEE, Hotel Sherman, Chicago, Ill. Oct. 13-15

American Institute of Electrical Engineers, Machine Tool Conference, Statler Hotel, Hartford, Conn. Oct. 13-15

Society of Industrial Packaging & Material Handling Engineers, Annual Exposition, Competition and Short Course, Chicago, Ill. Oct. 14-16

National Conference on Industrial Hydraulics, sponsored by Armour Research Foundation, Hotel Sherman, Chicago, Ill. Oct. 16-17

Institute of Radio Engineers, 1958 East Coast Conference on Aeronautical & Navigational Electronics, Lord Baltimore Hotel, Baltimore, Maryland Oct. 27-28

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A Functional Analysis of Automatic Logging Systems, February 1956, 16 pp. An examination of the various techniques and equipment used in performing the eight functions in a generalized automatic logging system: transducing, scale-factor correction and linearizing, derivation of quantities, scanning, analog-to-digital conversion, programming and control, alarm, and recording or logging. 50 cents.

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A Systems Analysis Predicts Performance, June 1955, 16 pp. This rare case history shows how determining the dynamic characteristics of both the process and the control system (and considering both open to modification) can reduce cost and improve performance. 50 cents.

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Controlling a Process—No. 9, December 1956, 5 pp. Explains why and how the various types of digital computers can be used as process controllers. 25 cents.

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Analog-to-Digital Converters—What Ones are Available and How They are Used—No. 11, April 1957, 12 pp. Describes techniques and lists commercial devices. 25 cents.

Fitting the Digital Computer into Process Control—No. 12, June 1957, 8 pp. Outlines a systematic approach to applying digital computers as process controllers and illustrates with a case in point. 25 cents.

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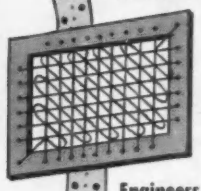
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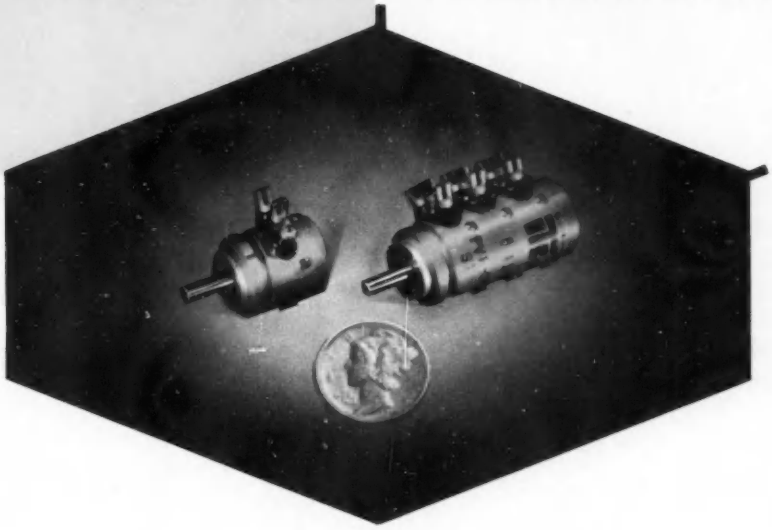
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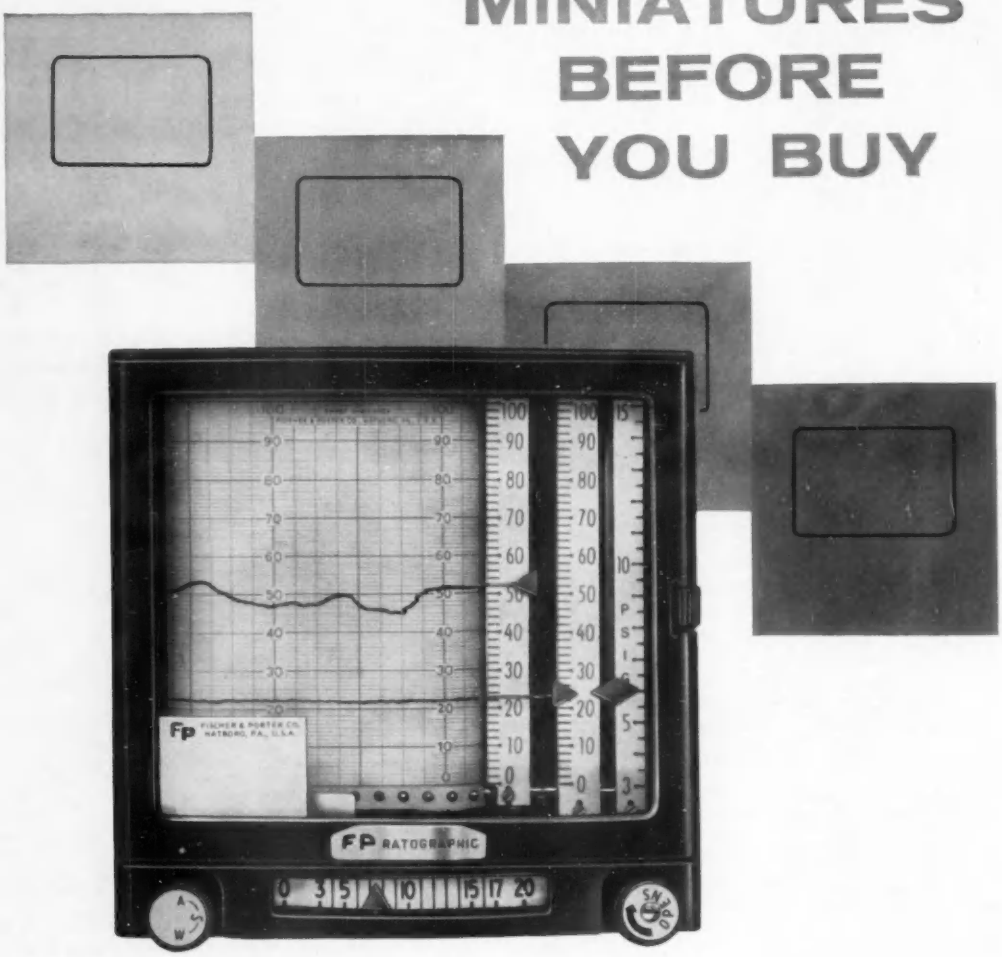
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